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MANICHAEAN INFLUENCE IN THE STONE CAVE CHAPEL OF KYUNGJU, KOREA

W. CARL RUFUS

GENERAL INTRODUCTION

Suk-kul-am, the Stone Cave Chapel, constructed on a mountain side in the southeastern part of Korea near Kyungju, contains excellent survivals of ancient Oriental stone sculpture. Yi Nung Hwa[1] says: "In the old capital of Silla there is a stone cave in which an image of Buddha, ten feet one inch in height [Korean measure], is seated at the center of the circular crypt. On the surrounding walls are carved other images of Bodhisattvas. The intrinsic beauty and skilful execution are foremost among the Oriental arts." This claim by a Korean writer is supported by American and English visitors. Professor Frederick Starr, after a description of the bas-relief wall images, adds:[2] "And in the center of all this beauty, this flowering of ancient art, sits the stone Buddha, on his lotus pedestal. It is a monolith, cut from a block of stone eleven feet in height. It is beautiful in pose, in feature, and in expression."

Madam E. A. Gordon gives an excellent description:[3] "In the center of the Cave is the indescribably beautiful image of Shaka Nyorai gazing eastwards towards the Sunrise, like the Great Sphinx in Egypt. It is carved in two kinds of stone, has a triple ring round the neck which distinguishes the early images of Buddha, and its rosy lips give an almost startling appearance of life as, creeping through the brushwood, one

[1] *History of Korean Buddhism* (in Chinese), Vol. III, p. 183. The passages were translated with the assistance of Mr. David W. C. Lee.

[2] *Korean Buddhism*, p. 71

[3] *Korea Branch of the Royal Asiatic Society*, Vol. V, Part I, p. 18.

suddenly and unexpectedly bursts upon it — a wondrous Vision of unearthly Peace and Beauty!"

Interest in the figures of the Cave is increased by the eclectic nature of its *theocrasia*. Elements of its imagery and symbolism, which are foreign to Buddhist art and iconography, present a perplexing problem. Madam Gordon has offered an explanation of some of these special features on the basis of Nestorian Christian influence. It is the purpose of this paper to propose another hypothesis, the influence of Manichaeism, which appears to be worthy of testing by means of further investigation.

HISTORICAL INTRODUCTION

Before presenting the problem a brief historical introduction will be given. Kyungju is a county seat in the southeastern part of Korea, which marks the site of a flourishing ancient city of the same name, the capital of the kingdom of Silla, 57 B.C. to 935 A.D. The following table of the chief periods of Korean history provides a setting for the time of Silla.

Periods of Korean History

1. Tangun, traditional	2333 B.C. to 1122 B.C.
2. Kija dynasty, quasi-historical	1122 B.C. to 193 B.C.
3. The Three Kingdoms:	
Koguryu (northern part)	37 B.C. to 668 A.D.
Pakje (southwest)	18 B.C. to 660 A.D.
Silla (southeast)	57 B.C. to 935 A.D.
4. Koryu (capital at Songdo)	918 A.D. to 1392 A.D.
5. Yi dynasty (Seoul)	1392 A.D. to 1910 A.D.

Ancient Kyungju was a center of art and industry wide in its influence. In its market-place there mingled Chinese, Japanese, Tibetans, Persians, Indians and even Arabians. In addition to overland commerce by way of Central Asia, it is claimed that trade was conducted by sea as far as Arabia and perhaps to Africa. The survivals of these palmy days of Silla indicate the height attained by Korean civilization.

The Half-Moon Fortress (See Plate I, Fig. 1) protected the capital from invasion. Within this enclosure merchants, artisans, priests, and kings contributed to the progress and prosperity of the race. Built in a section of the wall of the fortress is a stone ice-house. The Nine-Storey Pagoda was built by Queen Sun-dok in which to keep her jewels. The Silla Bell is twenty-three and one-half feet in circumference and weighs sixty tons. The inscriptions and ornamental designs show excellent workmanship and the tone is said to be unsurpassed.

The Astronomical Observatory of Kyungju was constructed in 647 A.D. (See Plate I, Fig. 2). Claim has been made (and not refuted) that this is the oldest structure extant and intact built solely for observational use. From its top I counted thirty-six mounds, the tombs of ancient royalty. Within these mounds are preserved excellent specimens of ornaments, pottery, and other works of art. These architectural and artistic survivals represent the civilization of ancient Silla, the setting for our study of the Stone Cave Chapel, which is ten miles from the ruins of Kyungju.

Another word of introduction is necessary regarding Buddhism in Korea. This religion originated in the Ganges Valley about 500 B.C. During its progress northward and eastward from India to Korea, where it arrived in the fourth century A.D., it came into contact with all the world religions of the day, and all the national cults of the countries through which it passed. The interfiltration of ideas among the great religious orders of that period presents a tangled web. Buddhism, syncretic in its nature, amalgamated in its "fluid and protean" system many beliefs, rites, and ceremonies, foreign to the teachings of its founder, Gautama. Concerning this characteristic of Buddhism, Bishop M. N. Trollope[4] says: "It has the most extraordinary capacity for absorbing into its system, and making part of itself, any religious beliefs, however alien to its first principles, which may be prevalent in the countries to which it goes." And speaking on Buddhism in Korea he said (with due apologies for the figure) that it had passed through "a drunken jazz of

[4] *Korea Branch of the Royal Asiatic Society*, Vol. VIII, p. 15.

religions" on its way from India; and he considers that the various contributing influences are inextricable.

Buddhism was introduced into Korea during the period of the Three Kingdoms. Sundo, a Chinese monk, reached Pyengyang, the capital of Koguryu, in 369 A.D. Received with royal favor, he was soon joined by others. Monasteries were established, virtually Buddhist universities in nature. Marananda, an Indian monk, came to Pakje a few years later in 384. Mukhocha, a black monk, is said to have introduced Buddhism into Silla about 424 A.D. Our chief interest in him is due to the fact that he is the reputed founder of the Stone Cave Chapel. Great mystery seemed to surround this man. Even his race is unknown.

THE CAVE CHAPEL

Mukhocha, Reputed Founder of the Cave Chapel

Yi Nung Hwa [5] gives the following account of Mukhocha: "During the reign of King Nulchi, Mukhocha came to Ilsun district, Silla, from Koguryu. A villager, Morei by name, made him a house to dwell in. The Liang dynasty of China sent an envoy to Silla and presented incense to the king. But neither the king nor the officials of his court knew how to use it or what it was. Hocha said: 'If you burn this, it will give out a fragrant odor; and you can use it in praying to the Gods, who are no other than the three Precious Ones, Pulta, Dharma, and Seungja. If you burn it and pray, there will be an answer.' At that time the king's daughter was sick. Hocha burned the incense and prayed. Then she was cured very soon. The king was pleased and rewarded him abundantly. Hocha gave Morei the presents that he had received from the king, disappeared soon, and nobody knew his whereabouts after that time."

There is an apparent inconsistency in this account which makes King Nulchi (417–458) contemporary with the Liang dynasty (502–557). This may account for the disagreement among various writers regarding the time of the introduction of Buddhism into Silla. Hulbert, Starr, Madam Gordon and others

[5] *History of Korean Buddhism*, Vol. I, p. 47.

place it about the year 424; while Ohlinger, Yi Nung Hwa, Bishop Trollope and others place it about a century later. We adopt the earlier date and offer the following explanation of the apparent inconsistency. During the dark period of Chinese history after the fall of the Former Chin dynasty near the end of the fourth century China witnessed the rise and fall of sixteen kingdoms within a century and a half. Eight nearly contemporary short-lived kingdoms were West Liang, North Liang, South Liang, South Chin, Posterior Liang, Posterior Chin, Posterior Wei and Posterior Yen.[6] Furthermore, according to W. Percival Yetts,[7] "For a short while at the beginning of the fifth century it [Tun-huang [8]] was the capital of the Western Liang." The strange gift to the king of Silla, said to have been sent by the Liang sovereign, probably came from the Western Liang, although there were other Liangs contemporary with Mukhocha. Again we have other evidence of the presence of Buddhism in Silla before 524. In 502 a Buddhist priest, who was given the privilege of the Silla court, was found hiding in the queen's quarters. This placed Buddhism under suspicion, so it had a precarious existence in Kyungju until its revival at the later date.

The Founding of the Cave Chapel

The story of Mukhocha is continued and much detail is added to the foregoing narrative. Mukhocha was said to be a messenger of Julai or Tathagata, but his action and reception were quite different from the experiences of Sundo and Marananda. Morei, his employer and benefactor, was compelled to hide him in a cave, which, strange to relate, became luminous by his presence. Even the garden outside became enchanted ground. Flowers of wondrous fragrance bloomed in midwinter and a peach tree glowed with five-colored blossoms. After the cure of the king's daughter, according to the extended account,

[6] *Outlines of Chinese History*, Li Ung Bing, p. 110.

[7] *Journal of the Royal Asiatic Society*, 1921, p. 136.

[8] The site of the famous Cave of the Thousand Buddhas in which valuable Manichaean documents were recently discovered and examples of Gandharan art may be seen.

Mukhocha begged the king to send to China and the West for artists to come to transform his cave dwelling into a chapel for the gods. They came and forty years were spent in fashioning the circular crypt and in carving the beautiful stone images to illustrate the religion of Mukhocha.

The Pictures of the Cave [9]

The Approach to the Cave (Plate II, Fig. 1). The Cave faces the rising sun. The flight of stone steps leading to the open

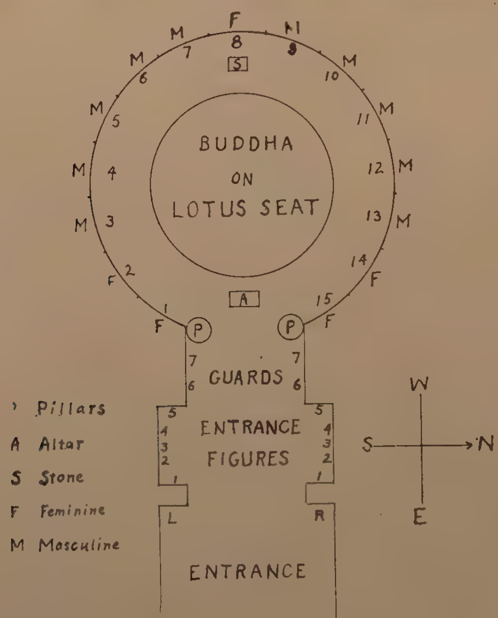

Fig. 1. Diagram of the Cave Chapel of Kyungju

entrance here appears in ruins. The dilapidated exterior has recently been repaired at the expense of the Government General of Chosen.

[9] For some of the photographs I am indebted to Mr. H. H. Underwood of Seoul. Others are reproductions from postcards and commercial prints. The list is merely representative and is in no wise complete.

The Vaulted Ceiling (Plate II, Fig. 2). The heavy roof is supported by a groined stone arch. This photograph of the low dome-like ceiling portrays the very ingenious locked stonework that has stood the test of fifteen centuries.

Diagram of the Cave (Fig. 1). On the walls of the entrance are carved fourteen figures, six generals, four spiritual guardians or *deva* kings, and four guardian demons. Within the Cave sits the Buddha with fifteen surrounding bas-relief figures. The arrangement by fives has not previously been noted: in the entrance are two groups of five, one on each side, clearly marked by the structure; within the Cave are three groups among the major bas-reliefs, two of masculine and one of feminine figures; also ten figures or two groups of five in the niches above the figures represented in the diagram; and a final group not so well arranged, composed of the Buddha and the four spiritual guardians.

Entrance Figure (Plate III, Fig. 1). The side view illustrates special features of the face. The broad flat outline, with little or no cavity for the eyes, is especially noticeable.

Spiritual Kings or Guards (Plate III, Fig. 2). The heavy armor represents transcendent power. Demons are put to flight or trampled under foot.

The Buddha (Plate IV, Fig. 1). This is the stone image of Buddha so enthusiastically admired by Madam Gordon. The elongated ears and urna of the forehead of the Indian ascetics are retained. The two guardian demons and the magnificent state of neglect and ruin are worthy of note.

Feminine Figures One and Two (Plate IV, Fig. 2). Interest centers in the feminine figures, which embody the chief exotic elements. They are excellent examples of the Gandharan or Hellenistic-Indian sculpture, which reached the height of its grandeur in the fifth century. This pair stands at the left of the entrance and a corresponding pair at the right. The elongated nimbus of the first, sometimes called 'boat-shaped,' and the circular nimbus of the second are clear, but other details are not well defined.

Masculine Figures Three and Four (Plate V, Fig. 1). Stand-

ing next to the preceding pair are two masculine figures. Racial differences characterize the group represented by these two. All wear long sacerdotal robes, while the first appears to be performing some priestly function.

Masculine Figures Twelve and Thirteen (Plate V, Fig. 2). Originally these figures and the preceding group were colored to indicate representatives of the different races. The various styles of foot-gear of the men are quite as interesting as the different styles of headdress of the women.

Feminine Figure Fourteen (Plate VI). "A majestic, queenly Woman." The Gandharan art is here seen at its best. We have the finely chiselled features, the graceful lines of the drapery, beautifully formed arms, and delicate hands. Special prominence is given by means of the lotus on which she stands. The interpretation of the symbolism of this figure constitutes the crux of the problem. Note the halo, the garment, the pendants, the crown and the cup. The cup as a special religious symbol is foreign to Buddhist art, but occupies a prominent place in Christian symbolism, and, as we shall point out later, it has unique significance in Manichaeism.

Feminine Figure Fifteen (Plate VII, Fig. 1). The last bas-relief follows the preceding and stands just at the right of the entrance. The boat-shaped halo, headdress and peculiar rod, are very similar to the corresponding figure at the left of the doorway.

The Upper Niches (Plate VII, Fig. 2). Above the fifteen wall figures are ten niches containing smaller figures, two of which are reproduced. The half-reclining posture or dreaming attitude of the one at the left should be noted.

THE APPROACH TO THE PROBLEM

The date of the original hypothesis of Manichaean influence and the early stages of the work may be given by quoting a letter of December 20, 1921, to Mr. H. H. Underwood, Seoul, Korea, who has kindly coöperated in obtaining material.

The hypothesis of Nestorian Christian influence to explain the non-Buddhistic imagery and symbolism of the Kyungju Cave Chapel was not convincing to me; but insufficient knowledge of the subject and lack of time to devote to it prevented me from looking for any other method of interpretation. Recently, impressed with the striking survivals of sun worship in the cave temple — its cryptic character, its orientation to the east, its nimbus-crowned figures and the "luminous" terms employed — I thought that this clue might lead to a new interpretation of the foreign elements. Accordingly I made a brief survey of Mithraism, the most popular and wide-spread religion of that kind during the early Christian era. Nearly all the symbols of the cave are found in Mithraic art: the "ceremonial [10] objects" find a natural place, as the rite of baptism was performed and a sort of communion using water or wine was celebrated in the subterranean Mithraea. However, the feminine figures did not appear to fit well in this interpretation, although some examples may be seen in Franz Cumont, *Textes et Monuments Figurés Relatifs aux Mystères de Mithra.* Also the omission of the most frequent theme, Mithra slaying the sacred bull, was noticeable, although the Buddhist setting would account for its absence. The clue seemed to be leading somewhere, so Manichaeism was attacked.

Manichaeism was the logical successor of Mithraism, not through organic relationship, but through the syncretism of its founder, Mani, who taught a mixed product of Christian-gnostic principles, Zoroastrian doctrines from which Mithraism may be traced, and other pagan ideas. A little reading in that field appeared to indicate real progress. I cannot go into detail, but will give two passages to show the nature of the resemblance found between Manichaean teaching and the Kyungju imagery and symbolism. A complete description of Manichaean rites and ceremonies and an exposition of its complex theogony, compared with a descriptive catalogue of all the images and symbols of the cave temple, would be necessary for a full treatment of the subject.

There is a subterranean scene recurring in various forms, sometimes almost defying analysis, a mixture of cosmogony and theogony, physical and spiritual elements intricately interwoven. A related theme is enacted in the following description of the departure of the soul of a true Manichaean, or rather his return to the Paradise of Light from a subterranean abode. Note the resemblance to the feminine figure of Kyungju with crown, garment and cup.

"The First Man sends to him a 'shining god of light' in the form of 'the Wise Guide' accompanied by three other gods and with them 'the bowl of water, the garment, the fillet for the head, the circlet, and the crown of light.' With them comes the *virgin* who is like to the soul of the just one. There also appears to him the devil of greed, that of pleasure and others. Directly the just one who is dying sees them, he calls to his help the goddess who has taken the form of the Wise Guide and the three gods, her companions. They draw near to him and at the sight of them the devils turn and flee. Then the gods take the Just One, do on him the crowns and the garment, put in his hand the bowl of water, and

[10] So styled by Madam Gordon.

mount with him to the Column of Praises in the sphere of the Moon, to the First Man and to Nahnaha the Mother of Life until they reach the place in the Paradise of Light he occupied in the beginning."[11] This may not be the exact scene represented in the Kyungju crypt, but the resemblance clearly indicates a close relationship.

One more quotation must suffice:

"Manichaean deities are represented like Bodhisattvas sitting cross-legged on a lotus. Mani receives the epithet Julai or Tathagata: as in Amida's Paradise, there are holy trees bearing flowers which enclose beings styled Buddha: the construction and phraseology of Manichaean books resemble those of a Buddhist Sutra."[12] You remember the picture of the Kyungju Buddha: sitting cross-legged on a lotus describes him well. Then Mukhocha was said to be a messenger of Julai or Tathagata, a name that was applied to Mani in Central Asia, as well as to Buddha: I do not know that it was restricted to these two persons; but its application to Mani supports the theory that the black monk bringing ideas, some of which are entirely non-Buddhistic and decidedly Manichaean, was in reality a messenger of Mani. The holy trees bearing flowers are also promiment in the tradition concerning Mukhocha and may be related to the perfumed garden of the Zoroastrians, or to the Five Trees of the Treasure House of the Gnostics.

Concerning the symbols used in connection with the virgin representing the soul of the Just One, no clear interpretation of their significance has been found. Legge (Vol. II, p. 187) makes the following suggestion from the *Pistis Sophia*:[13] "the *cup* of perception and understanding and wisdom which will make the soul seek after the mysteries of light, on finding which it will inherit light eternal; the *garment* of the heavenly nature with which the soul had to be clothed before it could ascend to the upper spheres of light; and the *crown* of protection against the spirits of evil." As Mani was acquainted with Gnostic doctrines and drew largely from them, it may be that this explanation is sufficient.

THE HYPOTHESIS APPLIED

We shall now test our hypothesis by applying Manichaean teaching to explain special features of the Cave Chapel. We shall consider the grouping by fives, the ten niches, the feminine and masculine figures and the central image.

The Grouping by Fives

Many of the ancient peoples regarded the number five as sacred to the God of Light. In the Manichaean pantheon it

[11] F. Legge, *Forerunners and Rivals of Christianity*, Vol. II, p. 309.

[12] Sir Charles Eliot, *Hinduism and Buddhism*, Vol. III, p. 216.

[13] A Gnostic work which escaped the orthodox-making process of the church fathers.

occupies a place of prominence, not with reference to the supreme gods, which constitute a triad or a pair of triads; but in connection with the Members, Powers, Aeons, and Angels of Light. The Manichaean system is dualistic, consisting of two eternal spiritual kingdoms, light and darkness, ruled by two beings opposite in nature and separate in origin, each with a host of subordinates. Various names are ascribed to these gods in the early Christian and later Mohammedan writings and in the Manichaean texts recently discovered at Turfan and Tun-huang. The God of Light or King of the Paradise of Light is the supreme being, the first person of the Manichaean trinity, who dwells in eternal Light. The second member is the Spirit of his Right Hand, sometimes styled the Mother of Light or Mother of Life, whose dwelling was the moon. The third person is the Primal Man, whose abode was the sun.

The God of Light has five members, intelligence, knowledge, thought, feeling and reflection. The Primal Man also has five members or powers, mild zephyr, cooling wind, bright light, clear water and quickening fire, who dwell in the kingdom of air between the kingdoms of light and of darkness. These are the spiritual essences of the five physical elements, ether, air, light, water, and fire. The Mother of Life does not have similar members. The God of Darkness has five powers, smoke, flame, darkness, scorching blast, and cloud. In a long struggle the Demon of Darkness overcame the Primal Man and dragged him down into the realm of darkness and the elements became inextricably intermingled. After the catastrophe the King of the Paradise of Light intervened by calling forth new Aeons, or Angels of Light, who succeeded in overthrowing the Powers of Darkness.

The number five appears again in the five orders of Manichaeism: (1) the teachers or masters, sons of gentleness; (2) the administrators, or sun-enlightened, sons of knowledge; (3) the elders or priests, sons of intelligence; (4) the elect, perfect or true, sons of discretion or secrecy; (5) the auditors or hearers, sons of enquiry or discernment.

Mani or Manes (216–275), Ambassador of the Light, also

styled the Great Tree, was the founder of Manichaeism and the head of the first order. He was a native of Babylonia; his father's name was Fatak and his mother, "Lady Mary," is said to have been a Parthian princess. Educated in the religions of his day, he received illumination in his thirteenth year. Later he attempted to harmonize the doctrines of all religious teachers, Moses, Zoroaster, Gautama and Jesus, with the resulting system outlined above. He began his teaching about the time of Ardeshir's restoration of the religion of Zoroaster and the collection of the Avestan texts, which was chiefly for the political purpose of binding together the newly-founded Sassanid empire. At first he met with royal favor; but the older Persian nobles preferred orthodox Zoroastrianism, and secured his banishment. He visited India, Turkestan, Thibet and China, gaining many converts. He returned to Persia and was put to death in 275 A.D. His followers suffered fierce persecution, but spread eastward and westward propagating his teachings, an attempted syncretism of all religions with an Avestan background.

Little is known concerning the higher orders of Manichaeism, as it was not only a religious organization, but also an effective secret society. In *Acta Archelai* the founder of the system was a slave who took the name Manes. He is said to have sent out Thomas, Hermas, and Addas, with special commissions. Although the story has usually been discredited, some confirmatory evidence has been found recently at Tun-huang, in the form of a sort of allocution addressed by Mani to Addas copied in Chinese.[14] The fourth order, sons of discretion or secrecy, was the missionary order, composed of both men and women. They were compelled by ordinance not to remain in one place, but to travel continually through all lands. If Mukhocha, the black monk, belonged to this order, the sons of secrecy, the mystery surrounding his actions and the uncertainty of his whereabouts are readily explained. As members of the order could not hold property or other possessions, the reason for giving to Morei the presents received from the king is apparent.

[14] F. Legge, *Forerunners and Rivals of Christianity*, Vol. II, p. 352.

The strange gift received by the king of Silla, said to have come from the Liang sovereign, looks like clever propaganda. The Chinese characters for the so-called incense are literally 'eye-sun,' as given by Madam Gordon. Koreans of the present day hesitate to admit the meaning and are quite as baffled as they were at the time of Mukhocha. Yi Nung Hwa uses another combination of characters to express incense, perhaps taking them from a different account. In the Vedas the eye of Mitra is the sun and we find this interesting passage: [15] "What the sun and light are to this visible world, that are the supreme good and truth to the intellectual and invisible universe; and as our corporeal eyes have a distinct perception of objects enlightened by the sun, thus our souls acquire certain knowledge, by meditating on the light of truth which emanates from the Being of Beings: that is the light by which alone our minds can be directed in the path of beatitude."

The appropriation of this sacred truth and the association of the mystic phrase, 'eye-sun,' with some foreign fragrant substance by Mani would be in keeping with his synthetic and secret system. To him light and good are not merely analogous, they are identical. Darkness and evil are one and the same. The physical and the ethical are not distinguishable. Redemption consists in freeing the imprisoned light from the darkness.

The fifth or lowest order were the auditors. Saint Augustine (354–430) belonged to this order for nine years.[16] Among the Tun-huang Manichaean texts is the *Khuastuanift*, the confession prayer of an auditor. In this we find that "It was a prescription to pray every day of the Moon-God, to God, to the Law, and to the Electi." Each one of the fifteen articles is a combination of profession of faith, confession of sins and repentance. The last one closes with the words: "To the resplendent Gods, to the Majesty of the Law, to the pure Electi, cleansing ourselves from sin! do we pray: our sins remit." [17] In accordance with

[15] H. A. Giles, *Religions of Ancient China*, p. 137.

[16] O'Conner, *Dissertation*, 1921, p. 7. St. Augustine's *Confessions*, Book III, Section 6.

[17] *Journal of the Royal Asiatic Society*, 1911, p. 299.

this prescription and this example Mukhocha, the founder of the Cave Chapel, enjoined prayer "to the gods, who are no other than the three Precious Ones, the first is Pulta, the second is Dharma, the Law, and the third is Seungja, the Holy Ones."

The number five recurring in the Manichaean system in these numerous ways and in others that might be mentioned, as the five classes of living creatures and five kinds of herbs and trees, which must not be injured on account of the inherent light, together with the ingenious grouping by fives in the Cave Chapel and other use of that number by Mukhocha, as the five-colored blossoms of the tree of immortality, strongly supports our hypothesis of Manichaean influence.

The Ten Niches

This appears like a logical continuation of the grouping by fives. Ten also corresponds with the tenfold heaven of the Manichaeans, as given in the *Khuastuanift*. The niche scenes may be intended to represent the steps by which an auditor could become a perfect by successive transmigrations. The soul must pass into the bodies of men and of animals, and during the intervals of time remain in a state like that of a sleeping man who is visited by dreams. The figures in the niches assume different attitudes including the one in a sleeping posture previously mentioned, and another of peculiar form, probably animal, and all together they seem to indicate the process of transformation.

The ten commandments of the Manichaeans taken in relation to their three (or four) seals also illustrate the tendency to adhere to a system of fives. Saint Augustine gives three seals, one of the mouth, one of the hand, and one of the heart. In eastern Manichaeism a generalizing fourth is found. Of the ten commandments three are kept with the heart, three with the mouth, three with the hand, and the tenth with the whole self. This interprets the phrases applied to a perfect,— good thoughts, good words, good deeds, and good religion.

The Feminine Figures

The kingdom of Silla signally honored women, having three queens as rulers, quite different from the customary Oriental practice. Also priestesses performed important functions at the four seasons when sacrifices were offered to the royal ancestors. During the reign of Nam-hai, the second ruler, his sister, Aro, presided at the sacrifices for King Hyuk-ku-sei, the founder of the kingdom.

Among the Cave figures we have already mentioned the Virgin of Light with crown, garment and cup, who represents the soul of a Manichaean perfect. This scene came from Zoroastrianism. On account of its fundamental significance in relation to the interpretation of the Cave figures we quote at length from two accounts as given in the Avesta.

> The thirtieth question is that which you ask thus: When a soul of the righteous goes on to heaven, in what manner does it go; also, who receives it, who leads it, and who makes it a household attendant of Auharmazd? Also, does any one of the righteous in heaven come out to meet it, and shall any thereof make enquiry of it, or how? Shall they also make up an account as to its sin and good works, and how is the comfort and pleasantness in heaven shown to it; also what is its food? Is it also their assistance which reaches unto the world, or not? And is the limit of heaven manifest, or what way is it?
>
> The reply is this, that a soul of the righteous steps forth unto heaven through the strength of the spirit of good works, along with the good spirit which is the escort of the soul, into its allotted station and the uppermost which is for its own good works; along with the spiritual good works, without those for the world, and a crown and coronet, a turban-sash and a fourfold fillet-pendant, a decorated robe and suitable equipments, spiritually flying unto heaven, or to the supreme heaven, there where their place is.[18] [19]

The following selection is taken from Yast XXII:[20]

> Zarathustra asked Ahura Mazda: "O Ahura Mazda, most beneficent Spirit, Maker of the material world, thou Holy One! When one of the faithful departs this life, where does his soul abide on that night?"

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[18] *Sacred Books of the East*, Vol. XVIII, *Pahlavi Texts* (edited by E. W. West), Part II, p. 63. Oxford, Clarendon Press, 1882.

[19] The entire reply is not quoted.

[20] *Sacred Books of the East*, Vol. XXIII. *The Zend Avesta* (edited by T. Darkesteter), Part II, p. 315.

Ahura Mazda answered: "It takes its seat near the head, singing the Ustavaiti Gatha and proclaiming happiness: 'Happy is he, happy the man, whoever he be, to whom Ahura Mazda gives the full accomplishment of his wishes!' On that night his soul tastes as much of pleasure as the whole of the living world can taste."

"On the second night where does his soul abide?" [The same answer is given.]

"On the third night where does his soul abide?" [After Ahura Mazda had repeated the same words as above, the text continues:] "At the end of the third night, when the dawn appears, it seems to the soul of the faithful one as if it were brought amidst plants and scents: it seems as if a wind were blowing from the region of the south, from the regions of the south, a sweet-scented wind, sweeter-scented than any other wind in the world. And it seems to the soul of the faithful one as if he were inhaling that wind with his nostrils, and he thinks: 'Whence does that wind blow, the sweetest-scented wind I ever inhaled with my nostrils?' And it seems to him as if his own conscience were advancing to him in that wind, in the shape of a maiden, fair, bright, white-armed, strong, tall-formed, high-standing, thick-breasted, beautiful of body, noble, of glorious seed (from the gods), of the size of a maid in her fifteenth year, as fair as the fairest things in the world."

And the soul of the faithful one addressed her, asking: "What maid art thou, who art the fairest maid I have ever seen?"

And she, being his own conscience, answers him: "O thou youth of good thoughts, good words, and good deeds, of good religion, I am thy own conscience!

"Everybody did love thee for that greatness, goodness, fairness, sweet-scentedness, victorious strength and freedom from sorrow, in which thou dost appear to me;

"And so thou, O youth of good thoughts, good words, and good deeds, of good religion! didst love me for that greatness, goodness, fairness, sweet-scentedness, victorious strength, and freedom from sorrow, in which I appear to thee. When thou wouldst see a man making derision and deeds of idolatry or rejecting (the poor) and shutting his door, then thou wouldst sit singing the Gathas and worshipping the good waters and Atar, the son of Ahura Mazda, and rejoicing the faithful that would come from near or from far. I was lovely and thou madest me still lovelier; I was fair and thou madest me still fairer; I was desirable and thou madest me still more desirable; I was sitting in a forward place and thou madest me sit in the foremost place, through this good thought, through this good speech, through this good deed of thine; and so henceforth men worship me for my having long sacrificed unto and conversed with Ahura Mazda."

The wicked soul is met by "a profligate woman, naked, decayed, gaping, bandy-legged, lean-hipped, spotted, like the most noxious creature, most filthy and most stinking."

The beautiful maiden of the Avesta representing the *fra-*

vashi[21] of a faithful Zoroastrian became the Virgin of Light representing the soul of a Manichaean perfect. Little transformation was necessary. The details of the Avestan description include "a crown and coronet, a turban sash, a fourfold fillet-pendant, a decorated robe and suitable equipments." The Manichaean description given by Legge includes "the bowl of water, the garment, the fillet for the head, the circlet, and the crown of light." The cup seems to be the only essential contribution. One meaning of the word Mani, which is cup or vessel, is suggestive. Evidently the cup had great significance in the secret mysteries. The close correspondence between the Avestan maiden, the Virgin of Light, and the Kyungju feminine figure with crown, halo, pendants, garment and cup, makes the identification seem unquestionable.

Concerning the significance of the cup, a suggestion may be made from the Avesta: "On the arrival of dawn (the third night after death), the treasurer of good works like a handsome maiden comes out to meet it (the soul) with the store of its own good works." Also among the equipments brought by the good spirits in the sunrise scene are "the spiritual good works, without those for the world." Is it not quite probable that the cup held in the hand of the personification of his good thoughts, good words, good deeds, his good religion, is the symbol containing the imperishable or spiritual part of the good works of a perfect Manichaean? It then acquires the added significance of the vital spiritual part of the departed, which is a second meaning of the name given to the founder of the system, Manes, the spirits of the departed. This provides a coherent explanation of the two apparently unrelated meanings, cup and spirit. The physical analogy accounts for the flowers enclosing "Buddhas" (not mortal ones), growing on the trees of immortality, and for the epithet, the Great Tree, which was also applied to Mani.

The central feminine figure of the Cave, a Kwannon, stands behind the image of Buddha, and wears a crown in which were

[21] Avestan name of a spiritual being, conceived as a part of a man's personality, existing before his birth, dwelling with Ahura in life and united with the soul at death.

set in niches ten (?) small heads, one of which has been removed. In her hand is the usual vase of ambrosia of the Chinese Kuan-yin. This figure appears to be a more refined type than the later images with eleven heads and a "thousand" arms. The origin of the many-headed being (not always eleven) is the legend of Avalokita: "May my head split asunder, if I fail in my vow to save beings." In Hastings' *Encyclopaedia of Religion and Ethics* we find that "The identification of Avalokita with the Sakti (female deity) par excellence, i.e., with the personification of the cosmic female energy, shows that the Chinese transformation of Avalokita into a woman had probably been effected in India." This gives a sound basis for identifying this transitional type of female Kwannon [22] as the Manichaean Mother of Life. As that person of the trinity is present in the scene of the departed soul, her image in the Cave was expected upon the basis of our hypothesis.

In addition to the Mother of Life and the Virgin of Light, the goddess who took the form of the Wise Guide and other light deities appear in the scene of the soul. The feminine figure standing by the Cave entrance at the side of the Virgin of Light may be the Wise Guide. The boat-shaped halo indicates the ability to sail the regions of light. The torch-like object carried may represent the rod of the Soul Guide with a function similar to that carried by Mercury.[23] One is tempted to turn aside to trace resemblances with the Grecian mysteries and with the older ones containing subterranean scenes. Ishtar descends to the lower world, where she is imprisoned, afterwards released, washed in the water of eternal life, and garments bestowed. Osiris was restored to life and immortality, aeons bringing vases of fresh water; he was purified by libations and fumigations, then fed, adorned and crowned.

There is a close correspondence between the pair of feminine figures, one at the left and the other at the right of the entrance. In this connection attention may be called to the "Twin Saviors" of the Pistis Sophia, whose duties are not defined. Also

[22] Usually masculine in Korea.

[23] Ernest Renan, *Études d'Histoire Religieuse*, p. 59.

two (or one) unidentified deities of the *Khuastuanift*, Kroshtag-Padwaktag, deserve mention. The translation of the passage regarding them and its *realia* gave difficulty to Le Coq. The deities are unquestionably "Light Bearers." The pair of similar feminine figures of the Cave are assisting light deities and may be related to the ones not clearly identified in the *Khuastuanift*. In the *Avesta* water and food are prepared for the departing soul. The Cave figure at the left carries a vase or water bottle. The one at the right holds two small objects that may represent the sacred cakes. If so, we find even the smallest details assuming definite meaning on the basis of our hypothesis.[24]

The Masculine Figures

Regarding the ten masculine figures, a single sentence from the sunrise scene is sufficient: "The souls of the righteous are gathered together there."

The Central Image

Upon the basis of our interpretation the central image of the Cave represents the Primal Man, who was also present in the Avestan scene. The Manichaean propagandists changed the name of their gods to identify them with the deities of the countries to which they went. This applied especially to the Primal Man. In North Africa among the Christians he was Jesus *patibilis;* in China he was the One, Great and Holy; in Persia he became Ormazd; in the Turfan texts, Zervan or Time; in the *Khuastuanift*, Khormuzta, the Youth. In this way the Manichaean became all things to all men and could pose as a good Christian, a good Zoroastrian or a good Buddhist. In the Cave Chapel the Primal Man became Sakya-yurai and is represented by the beautiful central stone image sitting on the lotus throne.

The Manichaean Khormuzta is identical with the contemporary Persian Ormazd, the real god of the Sassanid period. According to Hastings, he is "the One who was, who is and who

[24] The double-headed five-pronged thunderbolt suggests the function of Vajrin in the struggle against the demons.

shall be." He is omniscient, omnipotent, perfectly good, beneficent to all, benevolent and merciful. He foresees the struggle with Ahriman, the Demon of Darkness, and final victory. His dwelling place is eternal and boundless light. As god of the supreme law of justice and truth he desires all men to follow his path practising good words, good thoughts and good deeds, rejecting the works of the evil spirit, so they can reach the kingdom of blessings which is the reward of the just in this life and hereafter.

A FINAL QUESTION

One question remains to be considered. How did Gandharan art reach Korea as early as the fifth century? This type of stone sculpture was developed in Gandhara, a province of northwest India, during the early Christian era and reached the height of its grandeur in the fifth century. The main stream of its influence was limited to Buddhist art and passed through Persia, Turkestan, and China, reaching Korea and Japan in the seventh century. Sir Aurel Stein established the Persian link, when remains dating back to the Sassanid period were discovered. In the caves of Turfan and Tun-huang in Chinese Turkestan are many examples of Gandharan statues, although few are earlier than the Tang period. This art reached China, however, as early as the fourth century, when General Fu Chien (337–384) brought forty thousand Turkic families to his capital, P'ing Ch'eng.[25] It became the chief influence in the stone statues and bas-reliefs in the grottoes of Yun-kang, and modified by Chinese artists it was the chief factor in the Lung-men statues, and it left a permanent impression upon the Tang period (618–907).

In India at the beginning of the fifth century, the golden period of the Guptas (320–480) was at its height. Literature, art and science flourished. Numerous embassies were sent overland as far as China. There was a continual stream of Buddhist pilgrims along this well-traveled route. Kumarajiva reached China in 383. Marananda arrived in Pakche, the kingdom ad-

[25] John C. Ferguson, *Outlines of Chinese Art*, p. 99.

joining Silla, in 384. The Chinese pilgrim, Fa Hsien, returned to China in 414 after an extended tour through Central Asia and a lengthy sojourn in India.

The arrival of Mukhocha in Koguryu from India, Persia, or Turkestan, is readily explained, and his acquaintance with Gandharan art would naturally be expected. His request to send to China and the West for artists was in keeping with the condition of the times, as the descendants of the Turkic families in P'ing Ch'eng could supply the demand. Figures of a black monk are frequent in the Turkestan and Chinese grottoes, so it does not seem necessary to attempt to trace a separate racial descent of Mukhocha, the black monk of Silla. The discovery of Manichaean documents in Turfan and Tun-huang establishes the presence of this form of religion in Turkestan, the meeting point and melting pot of ancient eastern and western civilizations. On account of the large number of these early writings Eliot thinks that Turfan had an old and close connection with the west, suggesting the possibility that Mani may have preached there himself. After the tragic death of Mani upon his return to Persia, the persecution of his converts sent them east and west secretly preaching his religion. This practice continued several centuries.

Posing as a Buddhist pilgrim with a syncretic and adaptable religious system, Mukhocha could easily have passed through Central Asia, China and Korea, seeking a place in which he could propagate his religious views. With the vision of the sunrise scene of the soul guiding him toward the land of the rising sun, he was led to the mountain site near Kyungju. There, where he could witness the majestic splendor of the dawning of the day above the Eastern Sea from the open door of his cave abode, and breathe the sweet perfume of the flowers of his hillside garden, he sat in mystic contemplation. There, with the aid of Western artists, he depicted in beautiful form out of the solid rock the symbolic images and figures representing the soul at the dawn of eternity facing the ultimate realities of life.

University of Michigan

PLATE I

Fig. 1. The Half-Moon Fortress.

Fig. 2. The Silla Observatory

PLATE II

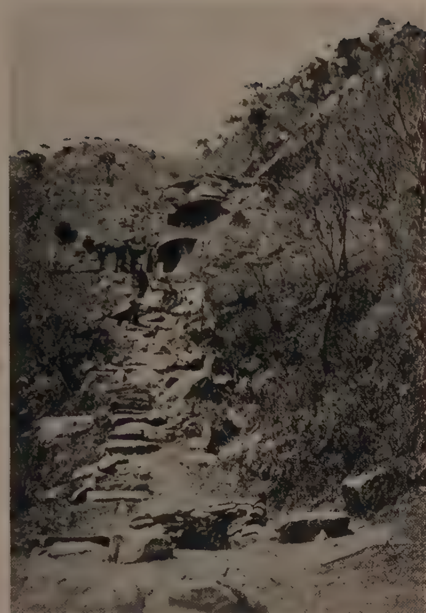

Fig. 1. The Approach to the Cave.

Fig. 2. The Vaulted Stone Ceiling.

PLATE III

Fig. 1. Entrance Figure.

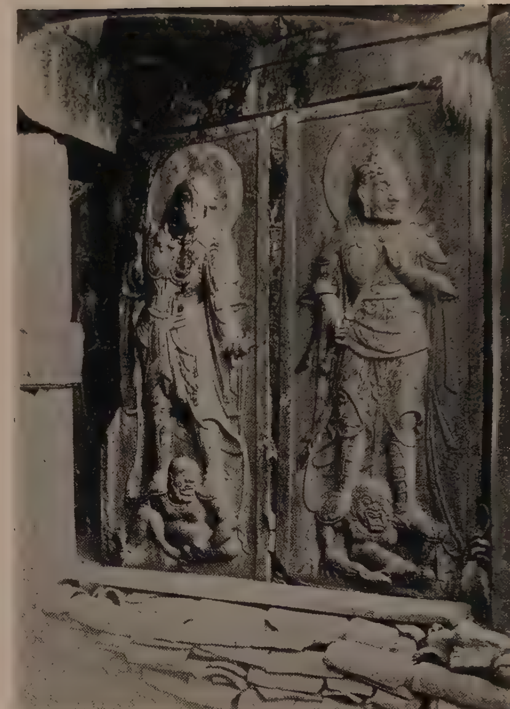

Fig. 2. Spiritual Kings.

PLATE IV

FIG. 1 The Buddha

FIG. 2 Feminine Figures One and Two

PLATE V

Fig. 1. Masculine Figures Three and Four.

Fig. 2. Masculine Figures Twelve and Thirteen.

PLATE VI

Feminine Figure Fourteen.

PLATE VII

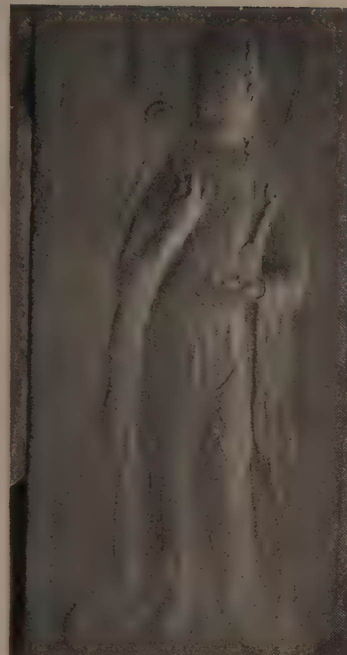

FIG. 1. Feminine Figure Fifteen.

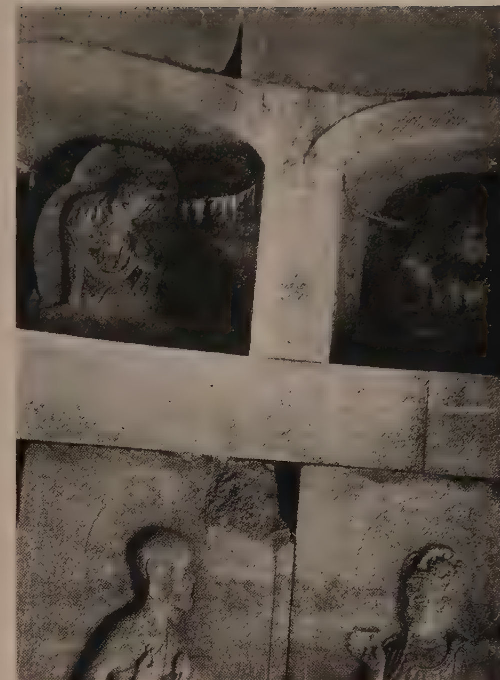

FIG. 2. Niche Figures.

FOSSIL LORE IN GREEK AND LATIN LITERATURE

EUGENE S. McCARTNEY

THE word fossil, which is of Latin extraction, is a derivative of the verb *fodio, fodere,* 'to dig.' The Latin form *fossile* is a translation of the Greek *orukton,* which means 'dug.' The Greek original seems to have no technical atmosphere about it, so that in rendering Greek authors who speak of fossil fish translators sometimes use the expression 'underground fish.' In a lake near Ruscino in Gallia Narbonensis people caught mullets (?) by digging down two or three feet and then plunging in a trident. The fish caught in this way were called 'dug mullets.' [1] The adjective is the same as the one in use for fossil fish. The Roman could speak of 'fossil salt' in the same way that he spoke of fossil animals.[2]

The Greeks and Romans naturally had many opportunities to examine fossils. Several of their temples are built of a shelly limestone and of course the beauty of many of their marbles, of which they were very fond, was greatly enhanced by fossils replaced by crystals.[3] In the classical countries fossils at times obtrude themselves upon one's notice. Just outside of Rome on Monte Mario I found many fine specimens of bivalves as large as the palm of one's hand. At Corneto one can still see in the fields shells as large as the crown of the head.

Along the Anio River in the deposits of travertine left by the overflow of the stream there are countless impressions of

[1] Strabo, 4. 1. 6. Cf. Lucian, *Vera Historia,* 2. 2.

[2] *Fossile sal,* Plin., *Nat. Hist.,* 37. 143.

[3] For ancient references to fossils in buildings, see Xen., *Anab.,* 3. 4. 10; Aristophanes *ap. Poll.,* 7. 100; Philostratus, *Vit. Apoll.,* 2. 20; Hesychius, s. v., Κογχυλίας λίθος.

twigs and leaves. The water is so saturated with calcareous matter that one can almost make impressions to order. The quarries below Tivoli, which were used to provide building stone for ancient Rome, are still being worked. Here it takes but a few days for an incrustation of lime to form about a twig placed in slowly trickling water.

So strange an occurrence as the finding of mineralized remains of animals would naturally stimulate any imaginative people to speculate about their origin. The discovery of impressions of fish in the earth led the Greeks to formulate some peculiar theories about them. Aristotle says that many kinds of fish live in the ground, but without moving, and that they are found by digging.[4] We learn from Aristotle's literary executor, Theophrastus, that fossil fish occurred in Paphlagonia. Since there was no water in the neighborhood and since the fish could not have had access to one another, he concludes that they were generated spontaneously.[5] According to him, these fish have their own habitat and their own peculiar nature, just as do the species found in sea and river.[6] The idea that fish were born spontaneously required no stretch of the imagination for a Greek. There were many kinds of fish, small animals and insects whose origin was accounted for in this way. Pliny [7] comments in regard to these fish that unless they have the same nature as creatures that live in the earth they make much less wonderful the subterranean existence of the mole.

We are told that fossil fish were found in a plain between the Pyrenees and the Narbo.[8] In Heraclea and in Pontus there were 'dug' fish which were unearthed along rivers especially and in moist places. Their presence in the earth was resourcefully

[4] *De Respiratione*, chap. 9.

[5] Pliny (*Nat. Hist.*, 36. 134) tells us that Theophrastus believed that there were stones which brought forth young, that bones were born from the earth, and that 'bone stones,' *lapides ossei*, were found. Darwin was amused to find people in South America discussing whether the fossil shells he had been collecting were "born by nature." See *The Voyage of the Beagle* (*Everyman's Library*), p. 338.

[6] *Frag.* 171. 11–12: cf. Pseudo-Aristotle, *De Mirab. Ausc.*, 74.

[7] *Nat. Hist.*, 9. 178.

[8] Polyb., 34. 10: cf. Athen., 8. 4.

explained. As some regions were drying up, the fish gradually followed the moisture down into the mud; when the earth had become dry, they remained in the moisture of the mud, in a lair, as it were. But whenever they were excavated before the return of the water, then they would move.[9]

On one occasion when the Romans were expecting a war with Macedon, there were several prodigies, among them the emergence of fish from the ground as the furrows were being turned.[10] There were ancient stories about people going fishing with mattocks, but our informant is careful to add that not every one believed that fish were dug instead of being caught.[11]

Peoples other than the Greeks have concluded that animals might live under the ground. During his travels in South America Darwin was shown some bones of mastodons in a cave. From the position of the fossil remains, the natives had conjectured that they belonged to burrowing animals.[12]

In northern latitudes of eastern Asia, teeth and bones of mammoths have been found embedded in cliffs and banks of rivers. Local geologists (or mythographers) formulated their own theory to account for them. They concluded that the earth was the natural habitat of certain creatures, and they tell of having seen the surface of the earth disturbed when the creatures moved beneath it. If by any misadventure the animals broke through and saw the light of day, at that very moment they died.[13] Some Siberians believed that the horns and teeth of elephants belonged to colossal rats which unawares broke through the surface and died on coming in contact with the air.[14]

A fossil that makes appeal to the popular imagination almost everywhere that it is found is the ammonite. Pliny [15] makes

[9] Pseudo-Aristotle, *De Mirab. Ausc.*, 73. For other references to 'dug' fish, see Athen., 8. 2; Strabo, 3. 42; 4. 16.

[10] Livy, 42. 2. 5: cf. Juv., 13. 65–66.

[11] Sen., *Nat. Quaest.*, 3. 16. 5 – 3. 17. 3.

[12] Darwin, *op. cit.*, p. 120.

[13] Page 54 of Von Olfers, *Die Ueberreste vorweltlicher Riesenthiere in Beziehung zu ostasiatischen Sagen und chinesischen Schriften, Abhandlungen der koeniglichen Akademie der Wissenschaften* (1839), 51–79.

[14] Von Olfers, *op. cit.*, p. 64.

[15] *Nat. Hist.*, 37. 167.

mention of *cornua Ammonis*, 'horns of Ammon,' that were found in Ethiopia,[16] and adds that they resemble horns of rams. They had the magic virtue of bringing to one dreams of things that were to happen.[17] In India "he who possesses a black *Salagrama* keeps it wrapped in white linen, washes and adores it daily. A draught of the water in which the shell has been washed is supposed to purge away all sin and to secure the temporal and eternal welfare of the drinker." [18]

Ammonites bear a closer resemblance to coiled snakes than to rams' horns and hence are frequently called 'snake-stones.' [19] The likeness is so real that attempts have been made to supply the missing heads and even to account for their loss. At Whitby they served as the coat of arms of the town.[20] Local tradition told how at the prayer of St. Hilda, the abbess of the convent, the snakes that inhabited the precincts not only suffered capital punishment, but were petrified.[21] A novel use for ammonites was made by the Glastonbury lake-village, of pre-Roman age, which has yielded several that were pierced as spindle-whorls.[22]

The 'deer-horn' stone, which so closely resembled horn that one could not readily tell whether it was horn or stone,[23] may have been a petrifaction.

[16] Isid., *Orig.*, 16. 4. 29, tells us that they occurred in Arabia as well as in Egypt.

[17] Cf. Solinus, 27. 46.

[18] Frazer, *The Magic Art*³, II. 26 and note. See also *Lectures on the Early History of the Kingship*, pp. 157–158.

[19] On ammonite lore see pages 49–60 of an article by W. W. Skeat *"Snakestones" and Stone Thunderbolts as Subjects for Systematic Investigation*, *Folk-Lore*, 23. 45–80. See also W. R. Halliday, *Snake Stones*, *Folk-Lore*, 32. 262–271.

[20] *Folk-Lore*, 17. 7.

[21] In *Marmion*, 2. 13, Scott thus refers to the story:

> ". . . of thousand snakes, each one
> Was changed into a coil of stone,
> When holy Hilda pray'd;
> Themselves, within their holy bound,
> Their stony folds had often found."

[22] Johnson, *Folk Memory*, p. 149.

[23] *Orphei Lithica*, p. 141 (Abel's ed.).

The geographer Strabo [24] saw at the foot of the pyramids heaps of stones some of which resembled lentils in size and shape. They contained substances like grain half peeled. The local explanation was that they were remnants of workmen's food converted into stone.[25] Strabo refutes this by saying that in his country, Amasia, a long hill in a plain abounded in pebbles of a porous stone resembling lentils.

Fossilized echini have long had popular ideas associated with them. In the Romano-British village of Rotherly, Wiltshire, many of them have been found.[26] It would seem that their presence in graves is to be ascribed to some supposed amuletic property. The Essex laborer believes that while a fossil sea-urchin is kept in his home he and his family will never lack bread.[27] These fossils are known as thunderstones in certain parts of Europe. They are believed to have fallen from the sky during thunderstorms and to act as a protection against lightning. If kept in an unfrequented part of the house, they make good substitutes for lightning-rods.[28]

A fossil which Pliny [29] describes as a kind of egg had the most wonderful powers ascribed to it in the land of Gaul. It was said to be formed from the saliva and slime of numerous snakes coiling together. The Druid version was that it was ejected into the air and had to be caught in a cloak before it touched the ground. The person catching it took to horse and was not safe until he put a stream between himself and the pursuing serpents. The test of its genuineness was its floating against the current, even when it was in a setting of gold.

The Druids praised it as bringing success in law-suits and gaining one access to kings. One specimen failed, however, with the Emperor Claudius, who put to death a Roman knight for no

[24] 17. 1. 34.

[25] It is said that "that at the base of the pyramids a variety of calcareous stone is found in detached masses, exactly such as Strabo has described, and appear to be the petrified remains of some unknown animal." See Falconer, *The Geography of Strabo*, III. 252, note 1.

[26] A. L. Pitt-Rivers, *Excavations in Cranborne Chase*, 2. 68, 78–85.

[27] Johnson, *Folk Memory*, p. 149.

[28] Blinkenberg, *The Thunderweapon in Religion and Folklore*, pp. 77–85, 95.

[29] *Nat. Hist.*, 29. 52–54.

other reason than his having possession of it. Pliny saw one that was rounded and about as large as a small-sized apple. The shell was cartilaginous and was remarkable for the number of its cup-shaped formations like those of the arms of a polypus.

The fossil described by Pliny is generally taken to be the echinus, but one dissenting voice [30] says that the passage "seems to point to some fossil covered with *Ostrea sigillina*, such as are common in British greensands." [31]

There was a Greek story to the effect that the Arimaspi, one-eyed men whom the Greeks assigned to the northern branches of the Ural, were in the habit of seizing gold from beneath griffins.[32] According to a traveler, the inhabitants in the Siberian tundras attribute the huge fossil bones they find to a colossal bird. He conjectured that the Greek tale originated from the excavating of "gold-sand lying under the formations of earth and peat, which are filled with fossil remains." [33]

In Pliny's *Natural History*, Book 37, there are classed as stones many geological specimens which would seem to be fossils: e.g., *hammitis*, like the spawn of fish (167); *lepidotis*, like the scales of fish (171); *meconitis*, like poppies (173) [34]; *brontea*, like the head of a tortoise (150) [35]; *nipparene*, like the teeth of a hippopotamus (175); *syringitis*, like reeds (182); *phoenicitis*, like dates (180); *phycitis*, like sea-weed (180); *spongitis*, like sponges (182).

Pliny (36. 139) [36] notes that there were several varieties of *ostracites*, which are evidently fossil shells. They were used as a substitute for pumice stone in smoothing the skin. Applied topically with honey, they arrested discharges of the blood and cured pains and ulcerations of the breasts. 'Idaean fingerstones,' which resembled thumbs, are probably belemnites [37] (37. 170).

[30] Conybeare, *Roman Britain*, p. 70.
[31] See also Brand, *Popular Antiquities*, s. v., *ovum anguinum*.
[32] Herodotus, 3. 16.
[33] *Erman's Travels in Siberia* (translated by W. D. Cooley), II. 87–89.
[34] Cf. Isid., *Orig.*, 16. 15. 20.
[35] Cf. *op. cit.*, 16. 15. 24.
[36] Cf. *op. cit.*, 16. 4. 16.
[37] The name 'fingerstone' is still applied to them in modern Europe. See C. Blinkenberg, *The Thunderweapon in Religion and Folklore*, pp. 76–77.

Cochlides, probably petrified shells, were used in Arabia as pendants for the trappings of horses (37. 194). Pliny (36. 134) speaks at second hand [38] of a white and a black fossil ivory. This would seem to be fossil teeth of mammals. The "osseous" stones that he mentions (36. 134) are apparently stones containing fossil bones.

An interesting fossil is the *glossopetra*, which resembles the human tongue, according to Pliny (37. 164).[39] It does not originate in the earth, but falls from heaven during the wane of the moon. It was requisite for selenomancy. Pliny distrusted the extravagance of the powers ascribed to it because of the claim that winds could be lulled by it. Among the modern names of *glossopetrae* are 'tongue-stones,' 'bird-stones,' 'swallow-stones,' and 'snake-stones.' In the seventeenth century the learned Dane, Nicolaus Steno, spoke of them as *Glossopetrae Melitenses*, 'tongue-stones of Malta.' [40] *Glossopetrae* have been identified as sharks' teeth.[41]

The ancients, too, had thunderstones (*ceraunia*,[42] *brontea* [43]). It was said that they were found only in places that had been struck by lightning.[44] They had various magical properties ascribed to them. A chaste person carrying the *lapis ceraunius* would never be struck by a thunderbolt, nor would the house or villa in which he might happen to be. One carrying it at sea was safe from bolts and squalls.[45] By means of it cities and fleets could be captured.[46]

There are several pieces of presumptive evidence which lead one to conclude that among these thunderstones were belemnites.[47] It would seem that some of the superstitions about such

[38] See Theophrastus, *De Lapidibus*, 6. 37.

[39] Cf. Solin., 37. 19; Isid., 16. 15. 17.

[40] See Winter, *The Prodromus of Nicolaus Steno's Dissertation* (*Univ. of Michigan Studies, Humanistic Series*, XI, part 2), p. 211.

[41] See *Die Kultur der Gegenwart* (*dritter Teil, vierte Abteilung*), IV. 344.

[42] Pliny, *Nat. Hist.*, 37. 132, 134–135.

[43] *Op. cit.*, 37. 150.

[44] *Op. cit.*, 37. 135.

[45] Damigeron, 12.

[46] Pliny, *op. cit.*, 37. 135.

[47] See Eugene S. McCartney, *On Fossil Thunderstones and Fingerstones The Classical Journal*, 18. 425–426.

fossils in widely scattered regions of Europe [48] have an unbroken tradition from antiquity.

The Greek and Latin literatures are replete with stories of the finding of huge bones. The remains have been disclosed as a rule through the action of rain, landslips and earthquakes, although other forces of Nature and the hand of man have aided. The theories that were framed ascribed them to remote ancestors of the human race who were exalted both literally and figuratively, to idealized heroes of a few centuries prior, to giants, and even to monsters. It would seem that whenever the accounts have any foundation in fact these huge bones are the remains of prehistoric animals.[49]

Aulus Gellius [50] asks what conclusion is to be drawn from such remains except that the bodies of remote ancestors were larger than those of contemporaries. The Christian writer Arnobius [51] is impatient with those who refused to regard the bones that were dug up in various places as convincing proof that in days of old men were demi-gods and heroes with bodies huge and vast. Virgil [52] recounts the prowess of an ancient warrior who picked up and hurled as he ran a large landmark (boundary stone) which twelve men of later mould could scarcely have sustained. St. Augustine [53] says that these discoveries prove the great size of the bodies of the ancients even to ages far later. Juvenal [54] regretted that in his day the earth brought forth only wicked and puny men.[55]

When stories record the finding of huge bones in coffins or tombs, it would seem that peasants or other persons had found

[48] See Blinkenberg, *loc. cit.*

[49] "Such stories probably sometimes originated in the discovery of the fossil bones of large animals." — Frazer, *Pausanias*, II. 483. See also Frazer, *Attis, Adonis and Osiris*, I. 157–158, and Von Ofers, *op. cit.*

[50] Noct. Att., 3. 10. 11.

[51] 2. 75.

[52] *Aen.*, 12. 899–900.

[53] *De Civ. Dei*, 15. 9.

[54] 15. 65. Cf. Solinus, 1. 87. Mayor, *Juvenal*, II. 374, gives other references.

[55] Not all the ancients were imposed upon by these huge bones. A certain Phoenix says that the size of the men of his day is sufficient evidence that heroes ten feet tall never existed (Philostratus, *Her.*, 1. 1).

the bones of prehistoric animals and had given them the rites of burial.[56] It may not be amiss to recall that there is a tombstone to Pithecanthropus in Java, although the remains no longer repose on the island. In view of the respect the ancients paid to the dead and their insistence upon proper burial rites, this does not seem at all strange. Some of the accounts, if they have any basis in fact, have been greatly enlarged upon.

Several interesting discoveries are recorded by Philostratus.[57] He says that the Lacedaemonians found in Nemea the corpse of Orestes,[58] which was seven cubits long; that when the sea destroyed the mound of Ajax, there were found bones belonging to a body eleven cubits long[59]; that during excavations on the island of Cos the earth opened exposing a body of twelve cubits, the head of which was inhabited by a dragon; that the body of Aryades, an Ethiopian or an Indian, whose resting-place was exposed by a landslip on the Orontes, was thirty cubits long. There is also a story to the effect that in digging the foundations of their city the Carthaginians came upon two skeletons, one of twenty-three cubits, the other twenty-four.[60]

On the prehistoric site of Phlegra in Macedonia there occurred a terrible fight with the giants for world dominion. Proof of the encounter was seen in the finds of enormous bones too large to be those of human beings. These were exposed whenever there was an unusually heavy deluge of rain. Ammunition dumps, so to speak, consisting of huge rocks for the storming of heaven were likewise pointed to in support of the story of the encounter.[61]

In describing the sanctuary of the boy Aesculapius at Megalopolis, Pausanias[62] says: "Here, too, are preserved bones

[56] See Mayor, *Juvenal*, II. 376.

[57] Philostratus, *Heroica*, 1. 2–3. See also Plut., *Thes.*, 36. 4.

[58] Cf. Herod., 1. 68; Plin., *Nat. Hist.*, 7. 74; Gell., *Noct. Att.*, 3. 10. 11; Solinus, 1. 90.

[59] Compare Pausanias, 1. 35. 5, where it is said that the knee-caps were about the size of the quoits used by boys in practising for the pentathlon.

[60] Phlegon, *Mirab.*, 18.

[61] Solinus, 9. 6–7. Herodotus, 7, 123, says that Phlegra is the ancient name of Pallene, the westernmost of the headlands of Chalcidice. See the text to note 65.

[62] 8. 32 .5.

of superhuman size; they were said to be the bones of the giants whom Hoplodamus mustered to defend Rhea." [63] Frazer comments as follows on this passage: "They were probably bones of mammoths. In the museum of Dimitsana in Arcadia there is a large partially-fossilized bone which was brought from Megalopolis and which the collector . . . calls the shoulder-blade of an elephant." Frazer thus comments on Pausanias, 8. 29. 1: "The localisation of the legend [of the battle of the gods and the giants] in the plain of Megalopolis may have been due to the prevalence of earthquakes, the burning earth, and especially to the finding of mammoth bones. Many such bones are still found by the peasants in this neighborhood, and some of them are now preserved in the museum at Dimitsana." [64]

Mention is frequently made of the discovery of remains of giants or of beings of gigantic stature. In the trunk of a brazen horse which was exposed by an earthquake in Lydia, the peasants found a corpse which seemed too large to be that of a human being. On a promontory of Sigeum there was brought to light the body of a giant that Apollo slew for defending Troy. It was twenty-two cubits long and so much of a curiosity that people made voyages to see it. A portion of a skeleton with the vertebrae of the backbone disjointed, presumably by an earthquake, was found in Lemnos. The skull was large enough to hold two Cretan amphorae of wine. In Cos bones of the 'earth-born' were discovered. So numerous were the bodies of giants that were found in Pallene exposed by rains and earthquakes that our informant speaks of them as bivouacking there.[65]

[63] Cf.: ". . . certain huge jaws and teeth, found in excavating on the Hoe at Plymouth, were recognized as belonging to the giant Gogmagog, who in old times fought his last fight there against Corineus, the eponymic hero of Cornwell." — Tylor, *Primitive Culture* [3] (1888), I. 387.

[64] For other tales of monsters and giants associated with the finding of huge fossil bones, see Tylor, *Researches into the Early History of Mankind*, pp. 314–315. See also pages 525–529 of Ernst von Lasaulx, *Die Geologie der Griechen und Roemer*, *Abhandlungen der philosoph.-philologischen Classe der koeniglich bayerischen Akademie der Wissenschaften*, 6: 515–566. Interesting notes are to be found in Mayor, *Juvenal*, II. 376.

[65] Philost. *Her.*, 1. 2–3.

Doubting a Libyan tradition that Antaeus was buried in the city of Tingis,[66] Sertorius [67] had a tomb opened in that place. On finding a body sixty cubits long, he was dumbfounded, and after sacrificing he filled up the tomb again and joined in magnifying its traditions and honors.[68]

An interesting piece of folklore grew up about what seems to be another tomb of Antaeus. Peasants in Mauretania pointed out a hill in which he was supposed to be buried. When any portion of it was dug out, rains began to fall and continued until the earth was replaced.[69] Ten feet longer than the skeleton of Antaeus was one which was said to have been found on an island near Athens. It measured 100 feet.[70] The honor of being the resting-place of the monster Geryon was claimed by both Lydia and Thebes.[71]

When an earthquake near the Strait of Messina had exposed enormous bones, the peasants were afraid to move them. A tooth over a foot long was sent to Tiberius, who was asked if he wished to have the other remains brought to him. He avoided the impiety of disturbing the dead by having a geometrician construct a face proportioned to the size of the tooth.[72] It is not strange that in Sicily, with its Homeric traditions of the Cyclopes and the Laestrygones, bones of prehistoric animals should be ascribed to the giants that were supposed to have inhabited the island.[73] It is said that Empedocles, too, accounted for them in this way.[74]

In a passage in *The City of God* [75] St. Augustine used the evidence of fossil bones to prove the existence of a race of giants: "But with regard to great size of body sceptics are very often convinced by the exposure, through lapse of time or the

[66] Strabo, 17. 8, says Lynx.
[67] Plut., *Sert.*, 9. 3.
[68] Barbarians in the Cimmerian Bosporus treated differently bones exposed by an earthquake. In their superstitious fear they threw them into the Maeotis marsh. Phlegon, *Mirab.*, 19.
[69] Pomp. *Mela*, 3. 10. 5.
[70] Phlegon, *Mirab.*, 17.
[71] Paus., 1. 35. 7; Luc., *Adv. Ind.*, 14.
[72] Phlegon, *Mirab.*, 14.
[73] Holm, *Geschichte Siciliens im Alterthum* (1870–1874), I. 57, 356.
[74] *Die Kultur der Gegenwart* (*dritter Teil, vierte Abteilung*), IV. 304. I have been unable, however, to find authority for this statement in the fragments of Empedocles.
[75] 15. 9.

violence of streams or by various chances, of tombs in which incredibly large bones of the dead have come to light or from which they have fallen out. Not only I myself but several men with me on the shore of Utica saw a molar so large that if it were cut up into small teeth the size of ours it seemed it could have made a hundred. But that, I believe, belonged to some giant." [76]

There were stories likewise of huge monsters. Marcus Scaurus exhibited during his consulship bones of a monster that were brought from a town in Judaea. It was said that Andromeda had been exposed to this creature. It was forty feet long; the ribs were longer than those of Indian elephants; and its spine was a foot and half thick.[77] In the same passage Pliny tells of a monster that was driven from the shores of Gades. Between the two wings at the end of its tail there was a spread of sixteen cubits; it had 120 teeth, the largest of which were nine inches long, the smallest, six inches.

Some of the ancients knew the significance of these finds of bones. Though remains found on the island of Capri were generally said to have been the bones of giants or the weapons of heroes, Suetonius knew they belonged to beasts and wild animals.[78] There was a tradition that huge bones found on Samos were those of the Amazons who were slaughtered while fleeing from Bacchus.[79] Later writers explained them as bones of animals.[80]

In the valley of the Arno there have been found remains of elephants and extinct animals which crossed from Africa on a land-bridge in Tertiary times. Nicolaus Steno, a Dane who lived in the seventeenth century, examined some of these bones and made some interesting if inaccurate deductions. We are told that the Carthaginian army entered Italy with thirty-seven elephants, but that they found the climate too rigorous for them. Livy (22. 2) represents Hannibal as riding the sole

[76] On huge bones in general see also Pliny, *Nat. Hist.* (cf. Solinus, 1. 91); Josephus, *Ant. Iud.*, 5. 23; (Pseudo-) Clemens, *Recog.*, 1. 29.

[77] Pliny, *Nat. Hist.*, 9. 11. [78] *Aug.*, 72. [79] Plut., *Mor.*, 303 E.

[80] Eugaion *ap. Phot.*, s. v., νηΐς; cf. Euphorion, *ap. Ael.*, *De Nat. Anim.*, 17. 28.

survivor when he rached Arezzo in the early spring of 217 B.C. Steno noted that the skulls, the huge femurs and the scapulae did not belong to animals native to Italy, and concluded that they were the elephants which Hannibal had brought with him into Italy.[81]

A recent article on the part played by fossils in mythology holds that the creators of the ancient cosmogonies with their giants and monsters had in mind mineralized remains which they had seen.[82] Furthermore, one finds not entire animals, but a tooth, a limb or a few bones. The conclusion is drawn that this is the basis of the ancient theory that in the original creation parts of bodies were formed separately in a more or less haphazard fashion, heads without necks, arms without shoulders, and so on, until fortuitous combinations of parts produced perfect bodies.[83]

Fossil lore is to be found in the early Christian writers also. They ransacked all branches of ancient science in order to find material to confirm the claims of the Bible. Just as they took the traditional notions of spontaneous generation to prove the possibility of the virgin birth of Christ, so they used the evidence of fossils found in the interior and on mountains as convincing testimony of Noah's flood. Eusebius [84] says that he confirmed with his own eyes the truth of the story that the deluge exceeded the height of the highest mountains. When building stone was taken from the highest quarries on Mount Lebanon, there were found in a perfect state of preservation various species of sea fish as large as hats,[85] patent testimony of the ancient flood.[86] He adds that persons who hear of these

[81] Winter, *op. cit.*, p. 258.

[82] M. Louis Siret, *Le Rôle des Fossiles en Mythologie*, *L'Anthropologie*, 32: 203–213.

[83] Such was the view of Empedocles. Compare and contrast Lucretius, 5. 837–854.

[84] *Chron.*, 1. 16. 12. Cf. Cedrenus, *Hist. Compend.*, vol. 35, p. 27, of *Corp. Script. Hist. Byz.*

[85] The *petasus*, a flat-brimmed hat.

[86] Cf. Tert., *De Pallio*, 2: Adhuc maris conchae et bucinae peregrinantur in montibus. See too Isidore, *Origines*, 13. 22. For the employment in rather modern times of the evidence of fossils to prove the reality of the flood of Noah, see Frazer, *Folk-Lore in the Old Testament*, I. 338-339.

things interpret them each one according to his own pleasure. He is referring evidently to pagans who used fossils as evidence of the flood of Deucalion.[87]

There are fashions in theories. The latest one is, not that fossils are proof of a deluge or of the deluge, but that they are in themselves the basis of the creation of stories of floods.[88]

References to fossilized vegetation and to petrifactions are comparatively infrequent in the classical literatures. Certain stones in the vicinity of Munda in Spain were described as being *palmati*,[89] a word that refers not to their size, but to the impressions of leaves within them, which were revealed when the stone was broken. *Dryitis*, 'oak-stone,' which resembled the trunk of a tree, burned like wood.[90] It has been conjectured that this was fossil coal. The isle of Samothrace gave its name to a heavy black stone resembling wood in appearance.[91] Among the metals of Scaptesula there was a stone closely resembling rotten wood. When one poured oil on it, it burned, but when the fire went out, it seemed to have been unaffected.[92]

An interesting passage in Pausanias runs as follows:[93] "I have heard a Cyprian, who was skilled in simples, say that the ebony-tree does not put forth leaves, and that there is no fruit on it — nay, that it is never seen in the sunlight, but consists of underground roots, which the Ethiopians dig up; for there are men among them who know how to find the ebony."[94] This is supposed to have been a fossilized wood.[95]

Along the whole coast of the Persian Gulf there grew trees resembling the laurel and the olive. When the tide ebbed, whole trees were visible above the water, although at high tide they

[87] A sentence in Apuleius, *Met.*, 41, "Me non negabunt in Gaetuliae mediterraneis montibus, ubi pisces per Deucalionis diluvia reperiuntur," has been taken as referring to fossil fish, but it is evidently a piece of sarcastic humor accounting for the presence of real fish in inland regions.

[88] See Siret, *op. cit.*, 32: 210.

[89] Pliny, *Nat. Hist.*, 36. 134.

[90] *Op. cit.*, 37. 188.

[91] *Op. cit.*, 37. 181.

[92] Theophrastus, *De Lapid.*, 17.

[93] 1. 42. 5; cf. *Hist. Plant.*, 4. 4. 6.

[94] Frazer's translation.

[95] Parkinson, *Organic Remains of a Former World*, I. 53.

were sometimes entirely covered. This seemed strange to Strabo because there were no trees back from the coast.[96]

Strange to say, the earliest speculation about fossils that I can find evinces a fairly clear understanding of their geological significance. By appealing to the evidence provided by shells and the petrifactions of marine life discovered on mountains and in quarries, Xenophanes, a philosopher of the sixth century B.C., endeavored to prove that the surface of the earth had once been beneath the waters of the sea. In the quarries of Syracuse he noticed the impression of a fish and of sea-weed(?) [97]; in Paros, that of a small fish called *aphua* [98]; in Malta, impressions of many kinds of sea life. He held that these changes took place when there was a stream of mud which later dried and kept the stamp or the imprint, so to speak, of the animals it overwhelmed. All humankind was destroyed when the land was thus carried into the sea; after this calamity man had to begin life anew.[99]

The finding on Delos and Anaphe of pebbles, shells and other things that are commonly washed up along shores was regarded as proof that these islands had once been under the sea.[100]

The ancients theorized about deposits of shells at great distances from the sea. Along a road three thousand stadia in length that led to the temple of Ammon, there was a great profusion of mussel-shells, oyster-shells, and scallop-shells. In Armenia, Matiene and Lower Phrygia, there were observed stones in the shape of bivalves, shells of the pecten order, impressions of scallop-shells. From the presence of sand and fossil shells in the extensive salt-lands of Egypt, the conclusion was

[96] Strabo, 16. 3. 6.

[97] The word 'seals' appears in the Greek text, but it has been held that seals are a paleontological impossibility for this region. A slight emendation of the Greek text gives 'sea-weed.' Fucoids have been found in great numbers in Sicily. See Gomperz, *Greek Thinkers*, I. 551.

[98] Whether rightly or wrongly the word was popularly interpreted as meaning 'not born.' It was generally believed that the fish originated from froth or foam.

[99] Diels, *Die Fragmente der Vorsokratiker* [3] (1912), I. 51.

[100] Theophrastus, *frag.*, 30. 3.

drawn that the land had once been submerged.[101] Diodorus [102] says that all Egypt was 'river-deposited.' Herodotus [103] and Plutarch [104] call attention to fossils upon the tops of mountains and conclude that Egypt was once sea.[105]

Most of the authors quoted in this paper are Greek. Roman curiosity was not so much aroused by fossils; in fact, their interest seems to have been rather bookish, since many of the Latin passages hark back to the Greek.

One will readily understand how difficult it was to form correct ideas about fossils in days before the theory of the evolution of plant and animal life had been formulated. Paleontology had to remain in the background until some of the other sciences were more fully developed. It is not so much to the discredit of the Greeks that superstitions existed among the rank and file of the people as it is to their credit that so many great men could cast aside traditional lore. It is remarkable that they were able to achieve so much without the microscope and other instruments and aids now regarded as indispensable. They were pioneers in many fields of thought and research, and it is the Greek spirit of scientific inquiry, the Greek endeavor to supersede a religious by a natural interpretation of the universe, that forms the basis for the attainments of modern science.

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[101] Strabo, 1. 3. 4; Pomp. Mela., 1. 6.
[102] 1. 39. 7. [103] 2. 12. [104] *Mor.*, 367.
[105] The poet Ovid, *Met.*, 15. 262–272, saw in the vicissitudes of the earth's surface a theme for poetic treatment.

THE HEART ROT OF BLACK ASH CAUSED BY *POLYPORUS HISPIDUS* FR.

DOW V. BAXTER

The black ash, *Fraxinus nigra* Marsh, is primarily a northern lowland species, but ranges from southern Newfoundland south to the West Virginia mountains, central Missouri, and northwestern Arkansas. Forest examiner, W. D. Sterrett (1), states that single forties may average 2,000 feet of black ash per acre, or about twenty per cent of the merchantable stand, and in very wet places single acres of nearly pure black ash will sometimes cut over 5,000 feet. The dark wood is inferior to that of white ash, but because of the many burls, it is highly prized for veneers. Its tough wood, being light, is also extensively used in the manufacturing of hoops and baskets. The black ash is now rated as the third most important ash commercially, and doubtless will remain an important timber tree because of its capability of growing on cold sites.

THE DISTRIBUTION OF THE FUNGUS AND ITS HOSTS

Field observations on black ash have been made over all of Michigan. These observations have been checked by a laboratory examination of five trees felled and sectioned for study, together with sound and partly decayed sections of other trees. These studies have shown that this heart rot of black ash is common thoughout the woodlots of the State. Elsewhere in the United States *Polyporus hispidus* has been reported from Kansas, Missouri, Ohio, Pennsylvania, New Jersey, and Florida. According to Lloyd (2), it might appear that *Polyporus hispidus* is rather rare in the United States; he also states that it is of a

southern range. Overholts (3) does not mention its frequency, and just records it for three states.

Polyporus hispidus is reported as a common form on ash trees in Britain, and Prilleaux (6) states that it appears in the Rhone Valley and at Cévennes on ash, and on apple and mulberry in Normandy. According to Tubeuf and Smith (7), plane and elm are given as hosts by Schroeter. J. Beauverie (8) states that in Europe this fungus attacks notably the fruit trees and especially the apple. It causes the death of the trees and brings about great damage in the cider-producing countries. Rea (9), in his recent treatise on the British Basidiomycetae, gives walnut as an additional host for this fungus.

The fungus is usually epidemic wherever it occurs throughout Michigan on black ash, and has never been found on any other host species within the State. White and black ash have been frequently observed where the former was attacked by *Fomes fraxinophilus* and the black ash by *Polyporus hispidus*. In none of these areas were the sporophores of *Polyporus hispidus* found on white ash, and no black ash trees showed indications of the *F. fraxinophilus* rot, although both fungi were abundant in the woodlots.

Murrill (4) states that *Polyporus hispidus* occurs occasionally on living trunks of oak and certain other deciduous trees, and that it is a very abundant and destructive enemy of shade trees in Europe. A specimen of this fungus on oak, collected near Scranton, Pennsylvania, is in the University Herbarium.

Although the field observations made for this study offer no direct proof of a selection of the host by the fungus, they indicate strongly that there is a possible occurrence of physiological strains with reference to ash and oak. It is hoped that further light may be thrown upon this subject by cultural experiments. Oaks are usually the dominant trees in the mixed hardwoods where the known epidemics of this fungus occur in Michigan. In spite of the most persistent efforts, *Polyporus hispidus* has never been found on the genus Quercus in Michigan, although it is known on the oaks and reported on various other deciduous species from other regions.

Little is known regarding the existence of biological strains among the wood-destroying fungi, but from our knowledge of other groups, it is possible to imagine that such forms or strains may exist among the Hymenomycetes. Atkinson (5) has already called attention to the fact that *Pleurotus ulmarius* Bull, while occurring on other frondose trees, is more common on the elm both in Europe and North America, although our native species of elm is different specifically from the European elm. Perhaps such wood-decaying fungi, which attack a few different hosts, specialize on a single host to which they have become adapted in that region. On the other hand, such types as *Fomes applanatus* and *Polyporus sulphureus*, which are found on a great variety of hosts, show little or no preference for a particular host. Should such specialization be the case for *Polyporus hispidus*, it would mean much in the planning of control measures.

THE SPOROPHORE

The fruiting bodies of *Polyporus hispidus* appear in the fall near branch stubs, in frost cracks, or wounds — usually in the upper portions of the main trunk. The mature and fresh sporophores are fleshy, moist, and brittle, but in dry condition may be reduced to a powder between the fingers. Because they are so easily destroyed by weathering and insects, the fruiting bodies are sometimes difficult to find, even though the rot itself may be common. As many as seven sporophores have been found, however, on the same tree.

The pileus is large (See Plate VIII), the dimensions being, $8.5-21 \times 5-13 \times 2.5-5.5$ cm. The surface is strongly hispid or hirsute, and is nearest to Mars brown (Ridg.) in color. The context is 1–5.4 centimeters thick, fleshy, brittle, and colored chestnut (Ridg.). The tubes are yellow-ocher and .5–1.5 centimeters long. The pores number 1–3 per mm. The color of the pileus blackens in age. The spores are broadly ovoid to ellipsoid, smooth, yellowish, brown, and measure $7-8.5 \times 6-7\ \mu$. Less than one per cent of the spores germinated in a ten per cent sugar solution after being sub-

jected to three months' drying at room temperature in the laboratory.

The sporophore resembles *Polyporus Schweinitzii* in color, but differs from that species in having larger spores, in the thickness of its context, in its sessile, dimidiate habit, and in its hosts. *Polyporus hispidus* occurs relatively high up on the trunks of frondose trees and has never been reported on conifers, while *Polyporus Schweinitzii* fruits usually at the base or from the roots of its coniferous hosts.

THE ROT AND ITS RELATION TO CARPENTER ANTS

(*See Text Figure 2, A and B*)

Polyporus hispidus attacks black ash trees of all ages, and especially the suppressed trees. The age of the five trees sectioned for this study ranged from fifty-three to one hundred and eighty years.

At the beginning of the study it was found that carpenter ants (*Componotus pennsylvanicus*) were associated with this rot of black ash. It was, therefore, necessary to determine whether or not the fungus gained entrance into the tree by ant channels, and if the fungus did enter by this means, whether it worked up into the bole. Trees bearing sporophores of *Polyporus hispidus*, showing no outward indications of ant work, were felled and found to be channelled in the basal sections. In one woodlot near Ann Arbor, approximately seventy-five per cent of the black ash trees had been blown over by a storm, leaving a characteristic three- or four-foot stump. The stumps were eaten out by ants until only a shell of the wood remained. Although the upper logs above the stumps were decayed by *Polyporus hispidus*, it was found that the weakening of the trees due to ant work was the direct cause for the windfall.

In this examination, I found that the carpenter ants bear no necessary relation to the rot, as sound sections of wood were secured in some of the trees, between the area destroyed by ants and that portion decayed by *Polyporus hispidus*. Sectioned trees

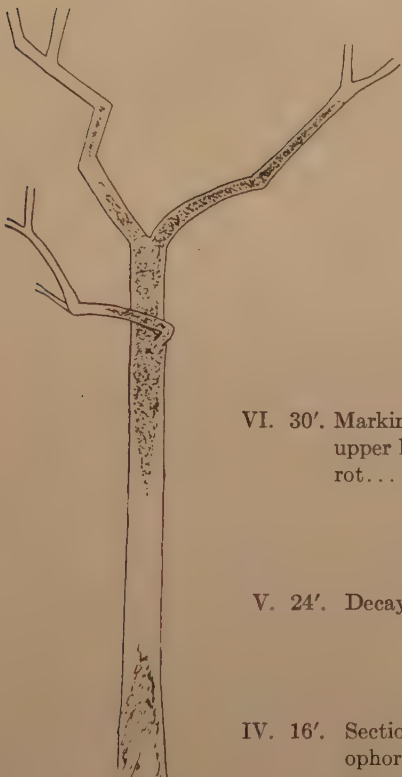

Fig. 2A. Diagram of badly decayed tree, showing upper portion of bole destroyed by *Polyporus hispidus*. Lower part of trunk is channelled by carpenter ants.

Fig. 2B. Diagram showing a method of sectioning used, and condition found in one of the trees. The figures at the side indicate the number of feet above ground.

Fig. 2A

VI. 30′. Marking the approximate upper limit of the visible rot. . . . .

V. 24′. Decayed. . . . .

IV. 16′. Section bearing sporophore . . . .

III. 12′. Indications of rot. . . . . .

II. 6′. Disk showing no connection between the area destroyed by carpenter ants and the part decayed by *Polyporus hispidus*. . . . . .

I. 2″. Channelled by ants. . . . .

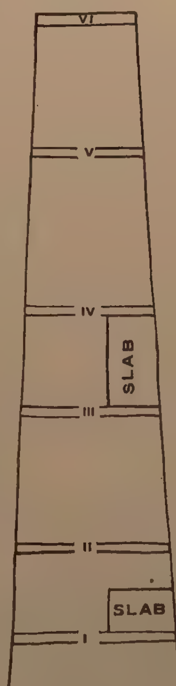

Fig. 2B

from other areas showed no signs of ant work, and clearly demonstrated that the fungus enters through branch stubs or wounds. The main rot, too, is usually confined to the upper part of the bole.

THE DISEASED WOOD

The dark wood of the black ash is changed by a partial delignification to a yellowish-brown color much lighter than that of the normal heartwood. The wood is reduced to a soft, spongy mass which is uniform throughout, and gradually advances into the sound tissues without any sharp distinction or discolorations between the wood first rotted and that not so far advanced. In this respect *Polyporus hispidus* apparently differs in its effects upon different hosts. Beauverie (8) states that a hard deep reddish-brown zone separates the young apparently sound wood from the heartwood which is completely decomposed. He is evidently speaking of Prilleaux's work on the decay of apple by *Polyporus hispidus.* On the ash, when a log is split lengthwise, the decayed portion dries out faster than the outer part and separates like a plug. As a result concentric layers may be formed from the shell of the wood still in good condition (See Plate IX). Dried cordwood from such trees separates and falls to pieces. This may also be seen in white ash attacked by *Fomes fraxinophilus.*

As a rule no definite black lines separate the so-called rotten and the apparently sound regions of black ash (See Plate X), such as are present in trees where the decay is due to *Fomes ignarius* or *Fomes Everhartii.* Bordering lines, however, may occasionally be observed in transverse sections, and irregular dark brown lines are very noticeable in certain areas of the most rotten wood when sectioned radially. This is due to discolored wood cells which are partially or entirely filled with a dark brown substance. A mottling effect consisting of very fine white lines running horizontally may also accompany the discolorations.

TABLE I

SOUND WOOD: SECTIONS SELECTED FROM ALL OF THE FIVE TREES

Kinds of Cells	Lignin Test	Cellulose Test
Medullary rays	Strongly lignified Stain a very deep red	Negative
Vessels	Strongly lignified	Negative
Wood parenchyma	Lignified	Negative
Wood fibers	A slight lignin reaction	Cellulose reaction

TABLE II

ROTTEN WOOD: CELLS CAPABLE OF BEING DISINTEGRATED AND CRUMBLED BETWEEN THE FINGERS

Kind of Cells	Lignin Test	Cellulose Test
Medullary rays	Parts of the cell walls indicated presence of lignin even in the last stages. Some of the walls were brown. Mycelium present.	Very slight in some sections; in others, negative.
Vessels	Like the ray cells, they are slow to break down. Walls or parts of walls give slight lignin test even in the most rotten wood.	Walls of these cells are brown. Mycelium present.
Wood parenchyma	Some cells give lignin test. The walls of some cells remain brown. Walls corroded. Mycelium present.	In most of the sections this test was negative. Some cells gave a faint celluose reaction.
Wood fibers	Principally negative, although a very faint positive test was noticed in some sections.	Cellulose present. Walls of many cells remained brown.

CHEMICAL TESTS

The fungus brings about a delignification of the elements, but the action is not complete. The starch grains which are so abundant throughout black ash wood disappear as the rot progresses.

Sections from five trees were stained with phloroglucin and hydrochloric acid for lignin reactions and chloriodide of zinc for cellulose reactions. Additional tests were made by the maule treatment,[1] and by the use of carbolic acid and hydrochloric acid.[2]

The preceding tables show the results of these tests.

The sections for these tests were selected from the most decayed parts of the five trees, but tests made of partially decayed wood gave similar results.

THE MYCELIUM IN THE TREE

Recent studies of wood-decaying fungi have been largely concerned in the distribution of the mycelium in the various portions of the tree. Kauffman and Kerber (10) pointed out that the mycelium of *Trametes robiniophila* may be found beyond the rot in apparently sound locust wood. They found hyphae present in relatively large numbers in sections made seven centimeters radially beyond the black zone. In the black border zone, however, it is stated that "no hyphae were observed in this zone, but evidence of their former presence was plentiful . . . If hyphae were present, they must have been overlooked because of the optical difficulties in the study of this zone." The question is raised by them as to what becomes of the mycelium in the rotten core inside of this black zone. It is well known that pockets of mycelium may occur throughout the decayed wood, but they were evidently not concerned with these features.

The question of what becomes of the mycelium of *Polyporus hispidus* in the most decayed wood of black ash does not at first seem to exist. Hyphae were observed many times in the most decayed sections of black ash, and this was possible even

[1] A drop of potassium permanganate solution is placed over the wood sections for a minute. Then hydrochloric acid is added until the color disappears. The wood is then treated with ammonia. Lignified tissues stain red. See *Beitrage zur wissenschaftlichen Botanik*, Vol. 4. Stuttgart, 1901.

[2] The sections are exposed to the sunlight for an hour after this treatment. Lignified tissues stain green. See Erdman West, *An Undescribed Timber Decay of Hemlock, Mycologia*, 11: 226. 1919.

without the aid of a stain. On the other hand, one may find badly corroded cells or even areas in which no mycelium is visible, or in which hyphae occur only occasionally. Von Schrenk (11) states that the mycelium is active in all parts of the diseased white ash decayed by *Fomes fraxinophilus*. I have also found no difficulty in locating mycelium of the same fungus in the rotten core of white ash. I have found similar conditions in wood badly decayed by a form of *Fomes fulvus* (Scop) Gillet on Crataegus. See photomicrographs of *Polyporus hispidus* (Plate XI), *Fomes fraxinophilus* (Plate XII), and *Fomes fulvus* (Plate XIII).

Little information is at hand regarding the development of the mycelium after the trees have been cut. When sections are first brought in from the field and placed in a cool moist room on glass, mycelium will grow out at the ends, but the growth soon stops. Sporophores have never been found on logs unless the trees had been recently blown down, and no cases have been observed where the fruiting bodies occur on old stumps. In this respect, *Polyporus hispidus* differs strikingly from some other heart-rotting fungi, notably *Fomes pinicola*. I have been able, however, to culture successfully *Polyporus hispidus* on artificial media.

A much greater part of the tree may be infected than is usually assumed or is obvious. In small pockets of even the apparently sound wood, wefts of mycelium often form small mats, usually in the center of the tree. I do not refer to the pith pockets, which remain even in old trees of *Fraxinus nigra*, but to the mycelium which may often be found in such regions bordering the pockets (See Plate XIV). It is usually necessary to split the logs lengthwise through the center in order that they may be seen, and even then a microscopic examination may be indispensable. Such mycelial mats were found in sections of black ash which otherwise showed no indications of rot, and were pronounced sound until they were split open. Mycelial wefts were found six feet above the area usually designated as rotten. The wood surrounding the wefts may at first appear sound, but mycelium has been found in such regions. Lumber cut from

TABLE III

Compression Tests of Oven-Dried Black Ash Wood

	Block Size (in inches)	Crushing Strength		Crushing Strength per square inch	
		1st fail	2d fail	1st fail	2d fail
Section with mycelial pocket, but wood apparently sound.	1. .87 × 1.64	11,780	12,550	8,256	8,795
	2. .76 × 1.70	10,160	10,610	7,863	8,212
	3. .84 × 1.69	9,630	9,660	6,783	6,804
Sound	1. 2.03 × 2.05	39,490	39,620	9,489	9,520
	2. 2.00 × 1.62	28,450	29,460	8,780	9,092
	3. 1.49 × 1.72	20,000	21,910	7,803	8,549
Extremely Rotten	1. .95 × 1.56	1,910	2,080	1,288	1,403
	2. 1.26 × 1.46	1,790	1,830	973	994
	3. 1.15 × 1.50	3,190	3,270	1,849	1,895

logs after the normal deductions for cull of such trees would naturally be of an inferior grade.

MECHANICAL TESTS

The extent to which the decayed wood is weakened by *Polyporus hispidus* was ascertained by testing oven-dried blocks for resistance to endwise compression. It must be kept in mind that such mechanical tests are relative, even in sound wood, and are very much more so in partially rotten sections. Wood varies with individual trees of the same species, and in different sections of the same tree. Such variables as the proportion of summer wood (12), the density, the kind and amount of seasoning, and other things, must be taken into consideration.

It will be observed, however, from Table III that large enough differences occur to warrant comparison of the tests obtained from sound black ash with those blocks tested from

sections in which a mycelial pocket was found six feet from the noticeably decayed area, and blocks taken from the most rotted sections. It may be seen that, in general, there is over a thousand pounds' difference per square inch in the first fail for the average sound blocks and the blocks containing the advanced mycelium.

CONTROL

The old infected trees in a natural stand, or those left by loggers, are a source of infection for the younger trees. Although very small black ash plants will grow in a reasonable amount of shade, they become more and more intolerant as their age increases. If the trees are growing in a dense stand, there results a weakened or suppressed condition favorable for the development of the fungus. This is in agreement with observations to the effect that *Polyporus hispidus* is usually epidemic in the localities where it is known in Michigan. Thinnings, therefore, of old stock will not necessarily simplify the control of the fungus. Silvicultural systems,[3] such as those recommended for half tolerant or intolerant species, should be employed.

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[3] *Shelterwood.* — This method aims at a complete removal of the old stand as quickly as possible and immediate reproduction. This is accomplished by a series of successive cuttings. The first cut allows light to come in. This system, however, demands most favorable economic conditions for its successful application.

Seeding from the Side: *Group Method.* — This method may be employed where there has been some accident such as fire, insects, etc. The system has not been used in the United States to any extent, as it requires windfirm species and very good forest conditions in order to assure success.

Clear Cutting. — With natural or artificial reproduction. Usually clear cutting is the cheapest method.

Coppice. — Coppice is probably the best method for the restocking of ash. *Polyporus hispidus* is principally a heartwood rot, and is usually, though not necessarily, confined to the upper part of the tree. Since sprouts from the black ash stumps do not form true heartwood for many years, it is doubtful whether the possible amount of infection from the stump would be great enough for consideration in actual practice.

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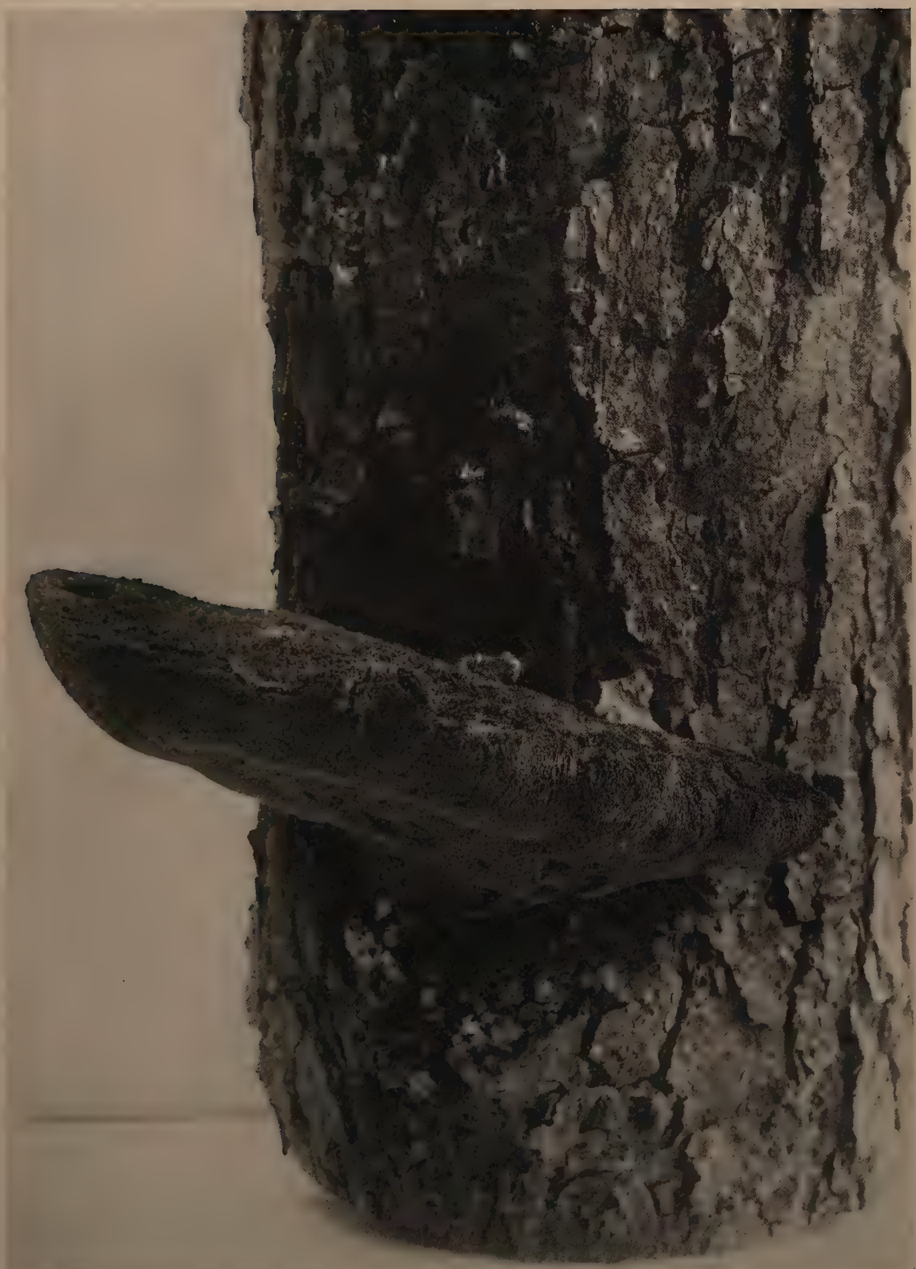
PLATE VIII



Sporophore of POLYPORUS HISPIDUS on Black Ash.

PLATE IX

Black Ash Decayed by Polyporus hispidus, showing Mottling and the Manner of Concentric Splitting.

PLATE X

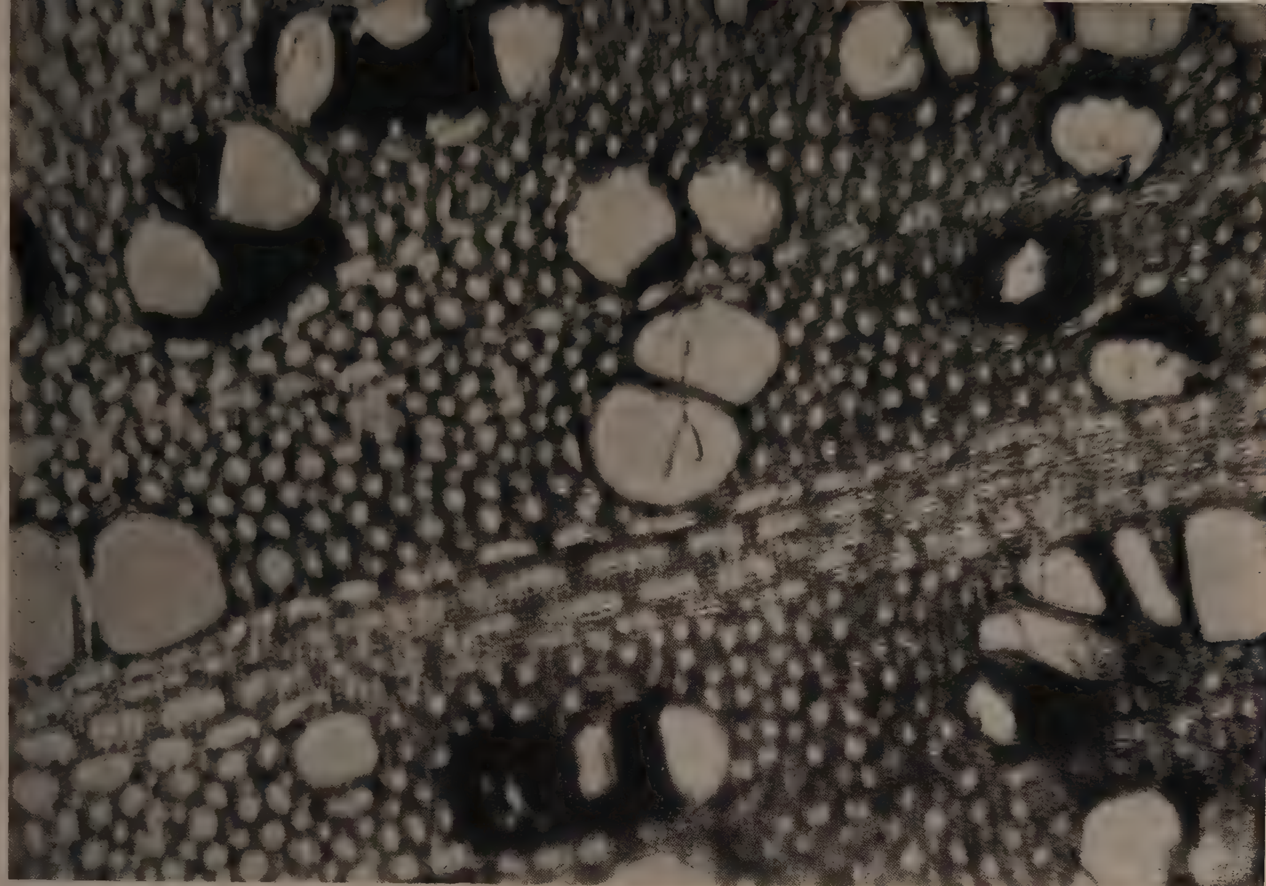
Rot of Black Ash Caused by Polyporus hispidus.

PLATE XI

Photomicrograph showing Mycelium of POLYPORUS HISPIDUS in Extremely Rotten Wood.

PLATE XII

Photomicrograph showing White Ash Decayed by FOMES FRAXINOPHILUS and Mycelium in Microscopic Pocket.



Photomicrograph showing Mycelium in Badly Decayed Section of Crataegus sp.

Decay produced by a form of Fomes fulvus (Scop.) Gillet.

PLATE XIV

Apparently Sound Wood of Black Ash showing Pith in Center of Section.

Mycelium may often be found in such regions.

THE COMPOSITION OF CLIMAX PLANT FORMATIONS IN MINNESOTA

H. F. BERGMAN

Several years ago, while I was located at the University of Minnesota, a study of the plant formations of the state was undertaken. The work was performed during the summer vacation periods for four years. During this time many data were obtained. For the most part these have never been worked up, although a preliminary paper on *The Development of Climax Formations in Northern Minnesota* was published in joint authorship with Mr. Harvey Stallard, a co-worker during the four years. The sequence of stages, their general composition and the effects of various causes on the composition of developmental stages in secondary succession were treated briefly. It is proposed in the present paper to analyze the composition of the climax plant associations.

There are three climax associations in Minnesota: (I) pine forest, (II) deciduous forest, and (III) prairie. All successions within a climax region terminate in the same final stage, however diverse they may be in their initial stages. Soil conditions and biotic agents may accelerate or retard the appearance of the climax. In some instances the retardation may result in the persistence of a developmental stage as a subclimax.

I. THE PINE FOREST CLIMAX

The dominant vegetation on well-drained soils over a large part of northern Minnesota is pine forest. In undrained portions within this region the Larix-Picea stage in hydrophytic succession has persisted as a subclimax. The Larix-Picea subclimax occurs

over a very large part of the area occupied by glacial Lake Agassiz.

The dominants of the pine forest climax are *Pinus strobus* and *P. resinosa*. These are usually interspersed, or in some instances *P. resinosa* may be found as a pure dominant over areas of considerable extent. This has not been found to be true with *P. strobus*.

All the large tracts of pine have disappeared as a result of lumbering. The distribution of pine stumps on lumbered and burned-over lands indicates the composition of the formerly dominant vegetation of a large part of northern Minnesota. The few small isolated areas which remain give quite an accurate idea of the conditions which must have existed over the climax region as a whole. From quadrat studies in existing pine communities and from counts of stumps, it is found that in the older pine forests the density of population is 8–12 trees per quadrat of 100 sq. m. In stands of younger pine this may increase to 15–18 or even somewhat more.

Other trees occurring with pines in the climax association are: *Abies balsamea*, *Betula papyrifera*, *Picea canadensis* and *Populus balsamifera*. They constitute only a small percentage of the population in all cases and are usually trees of smaller diameter than the pines. The relative importance of the various trees found in this association is shown by the following figures. In nine quadrats the total number of individuals of each kind found was: *Pinus strobus*, 23; *P. resinosa*, 30; Betula, 56; Abies, 126; Picea, 5; Thuja, 1; Populus, 2. Abies and Betula greatly exceed any of the others in number, but only one Betula and ten Abies were found with a trunk diameter exceeding 1.5 dm. None of the other trees present exceeded this size. Betula, Picea and Thuja may reach a large size under suitable conditions.

The largest trees present were white pines, 13 per cent having attained a trunk diameter of more than 7.5 dm. The smallest white pines were 3–4.5 dm. in diameter; these constituted nearly 35 per cent of the total number present. Of the intermediate sizes 30 per cent were from 4.5–6 dm. and the re-

mainder, approximately 22 per cent, were from 6–7.5 dm. in diameter.

Pinus resinosa does not reach as great a size as *P. strobus* apparently. Of the 30 individuals in the nine quadrats, only 1 individual, or $3\frac{1}{3}$ per cent, had reached a diameter of 6 dm.; $56\frac{2}{3}$ per cent were between 4.5–6 dm.; $36\frac{2}{3}$ per cent between 3–4.5 dm.; and $3\frac{1}{3}$ per cent were less than 3 dm. in diameter.

The mature forest is thus found to consist of two dominants, *Pinus strobus* and *P. resinosa*, both of which reach a size which probably represents an age of 300–400 years. The distribution of trees according to trunk diameter indicates that ecesis is periodic. It is to be noted that in the nine quadrats considered, only one pine (*P. resinosa*) occurs which is less than 3 dm. in diameter and that there are none, either of *P. strobus* or *P. resinosa*, less than 1.5 dm. The absence of trees from the seedling stages up to a diameter of 1.5 dm. makes it clear that no pines have been able to become established in the forest, at least in the areas represented in the quadrats, during the last 20–30 years. From this it might be inferred that the forest is not self-perpetuating.

An examination of a few quadrats in a pine forest from which some of the trees have been cut reveals the conditions under which ecesis takes place. In seven quadrats from three localities the invading population of open stations in the pine forest was distributed as follows: Abies, 52; Betula, 15; Picea, 6; *Pinus banksiana*, 34; *P. resinosa*, 321; *P. strobus*, 112. It is seen that when an opening appears in the forest the area is occupied by seedlings of various trees among which *P. resinosa* and *P. strobus* are the most numerous. Under natural conditions the openings provided for invasion are due to windfalls. These may and usually do occur as isolated individuals, but in severe storms a number of adjacent trees may be blown over. The invaders of these areas grow up together, a process that results in severe competition which ends in the elimination of the more slowly growing individuals, or of those less able to endure shade. *Pinus banksiana* when present is the first to disappear.

Abies, although numerically important, does not reach a large size ordinarily. Its persistence is due mainly to its ability to tolerate shade. Most of the individuals of Abies and Betula are soon suppressed, as shown by the fact that they seldom grow to a diameter of 1.5 dm. Dead trunks of Abies and Betula, both standing and fallen, give further evidence of their inability to compete with the pines. In some instances Abies, Betula or Populus may grow to a considerable size, in the case of Betula and Populus to a diameter of 6 dm. or more. This happens only when simultaneous invasion of an open area in the pine forest by these trees and pines occurs. Even under these conditions they will ultimately be eliminated in competition with the longer-lived pines. The presence of Abies, Betula and Populus may then be taken as evidence of the immaturity of the association. But as the association is made up of a great number of subseres in windfall areas of different ages in which Abies, Betula and Populus may invade simultaneously with pines, there is a probability of finding any of these trees somewhere in the association. The figures given, however, show that they are numerically unimportant in comparison with the pines and that the Pinus association is capable of perpetuating itself under normal conditions.

Secondary Species. — The undergrowth in a mature pine forest is sparse. The following shrubs are usually present:

Acer spicatum	Diervilla lonicera
Alnus crispa	Lonicera oblongifolia
Corylus americana	Vaccinium canadense
Corylus rostrata	Vaccinium pennsylvanicum

Acer, *Corylus rostrata* and Lonicera usually occur in lower places. They are characteristic of preceding stages in hydrophytic succession. The others occur on higher, drier ground, especially in areas of sand or on rock. They are characteristic species of the xerosere. *Arctostaphylos uva-ursi* also occurs in xeroseres in sandy soil. As conditions approach mesophytism in the climax forest the undershrubs peculiar to the two different lines of development become more or less interspersed.

In addition to the shrubs the following plants occur as characteristic vegetation of the ground layer:

Aster macrophyllus	Chimaphila umbellata
Cornus canadensis	Pyrola americana
Gaultheria procumbens	P. secunda

II. THE DECIDUOUS FOREST CLIMAX

This is most typically developed in the southeastern part of the state extending as far northward as Minneapolis. Subclimax dominants representing the association extend to the extreme northwest corner of the state, forming a zone of variable width between the pine and prairie grass regions. Small isolated areas showing typical development of the association are to be found in some localities within the pine climax region.

The typical dominants of this association are *Acer saccharum* and *Tilia americana.* Other trees occurring with them as dominants are: *Carya cordiformis, Carya ovata, Fraxinus americana, F. lanceolata, F. nigra, Juglans cinerea, Quercus alba, Q. rubra, Q. macrocarpa* and *Ulmus americana.*

Exclusive dominance of any one is unusual, although in the mature association Acer and Tilia are present in greater numbers than any of the others. Within small areas Acer may be an exclusive dominant. The following figures will show the relative importance of the various consocies. In a total of 17 quadrats of this association Tilia was found in 15, Acer and Ulmus in 10, *Carya cordiformis* and *Q. rubra* in 7, *Q. alba* in 6, *Fraxinus americana* in 4, *Quercus macrocarpa* in 3, *Fraxinus lanceolata* in 2, *Carya ovata, Fraxinus nigra* and Juglans in 1. In order of total number of individuals present Acer ranks first, Tilia second and *Carya cordiformis* third.

A measurement of the trunk diameters of the trees in ten quadrats of 100 sq. m. shows that only five of the consocies listed exceed 4.5 dm. These are Acer, Tilia, *Fraxinus nigra, Quercus alba* and *Q. rubra.* Acer ranks first with the greatest number of trees of largest size, often attaining a diameter of 6–7.5 dm. Tilia ranks second, but with a considerably smaller

proportion of large trees. *Quercus alba* and *Q. rubra* follow in order of importance, the former ranking only slightly higher than the latter. In the case of Acer and Tilia the distribution of trees by classes based on trunk diameter is quite uniform from the maximum size down to 1.5 dm. The great abundance of seedlings and small trees up to a diameter of 1.5 dm. found in openings in the climax forest indicates that, whenever an opening occurs as the result of a windfall or other cause, the area is at once invaded by Acer and Tilia and that the association is self-perpetuating.

Although seedlings and young trees of *Q. alba* and *Q. rubra* are not often found they do occur occasionally. Seedlings of Carya, Juglans and Ulmus have been found in many instances in quadrats in the climax forest. Saplings of these trees do not occur, a fact which indicates that they do not become established under these conditions. On the other hand in places where the climax forest has been removed more or less completely, seedlings and saplings of varying ages occur frequently. The presence of these trees in the dominant layer of the climax forest may be due to the relative youth of the plant community in which they occur. Such a community consists of the survivors of contemporaneous invaders of an open or relatively open area among which the ultimate outcome of competition is not yet apparent.

Hence it follows that the mature climax association is represented by only two consocies, Acer and Tilia. In some cases the deciduous forest climax may be represented entirely by a preclimax associes of Ulmus, Fraxinus and Quercus, or by a Quercus associes in which *Q. macrocarpa*, *Q. coccinea* and sometimes *Q. alba* and *Q. rubra* are the dominants. The Ulmus-Fraxinus associes occurs typically along streams in the ecotone between the prairie and the climax deciduous forest. It may appear as a stage in the development of the hydrosere, or as a stage in the xerosere in soils of moderate water content and in more protected situations. It is this associes as a preclimax which to a great extent represents the deciduous forest from Mankato and Minneapolis to the northwest corner of the state.

The Quercus associes appears as a stage in the development of the xerosere in soils of low water content and in more exposed situations. It also occurs in the tension zone between the prairie and the climax deciduous forest. It constitutes a preclimax to the Acer-Tilia forest in areas where edaphic and biotic factors act as a barrier to the advance of the latter. This associes attains its best and most extensive development in the areas of sand located along the Mississippi River from Minneapolis to Brainerd. In this area *Q. macrocarpa* and *Q. coccinea* are the dominants.

In the southern part of the Pinus climax forest region the Acer-Tilia climax is becoming established in many places following the removal of the pines by lumbering and burning. In such areas *Fraxinus nigra* occurs very commonly as a dominant in the deciduous forest. It attains a size quite comparable to that of Acer and Tilia. The abundant occurrence of seedlings and of trees ranging in size from seedlings to those of 6–7.5 dm. in diameter shows that it is able to maintain its status as a dominant in the mature forest.

Secondary species. — *Ostrya virginiana* occurs commonly as a small tree below the layer of dominants. *Carpinus caroliniana* occurs in the southeastern part of the state. The following shrubs and woody climbers are characteristic:

Corylus americana	Ribes cynosbati
Parthenocissus quinquefolia	Ribes gracile
Prunus americana	Rosa blanda
Prunus virginiana	Vitis vulpina
Ribes floridum	Xanthoxylum americanum

The herbaceous layer is dense and consists of a large number of species. Some of the more characteristic ones are:

Actaea rubra	Carex laxiflora
Aquilegia canadensis	Fragaria virginiana
Arisaema triphyllum	Hepatica triloba
Bicuculla cucullaria	Hydrophyllum virginianum

Phlox divaricata	Trillium cernuum
Polygonatum commutatum	Uvularia grandiflora
Sanguinaria canadensis	Viola papilionacea
Sanicula marylandica	Viola pubescens
Thalictrum dioicum	Viola sororia

III. THE PRAIRIE CLIMAX

In a considerable part of southwestern and western Minnesota forest has not been able to become established, because of lesser rainfall and greater summer evaporation. This area is occupied by the prairie climax. Soil conditions and disturbance by burning have been contributory factors in the extension and maintenance of the prairie in some districts.

The dominant grasses of the prairie are: *Andropogon furcatus*, *A. scoparius*, *Atheropogon curtipendulus*, *Sorghastrum nutans*, *Bouteloua oligostachya* and *Stipa spartea.* These may be associated in various combinations. Usually Andropogon, Sorghastrum and Stipa occur together occupying areas of higher water content. They are the characteristic consocies in the development of hydroseres culminating in the prairie grass association. *Andropogon furcatus* is equally characteristic in xeroseres, either primary or secondary, on sandy soils. In this case *Andropogon scoparius* usually occurs with it as a dominant instead of Sorghastrum and Stipa. *A. furcatus* is the most important member of the association, both in the hydrosere and in the xerosere. In some areas it may constitute 75 per cent or more of the dominant vegetation.

Secondary species. — More or less marked differences are to be observed in the character of the secondary species in the prairie climax according to the line of development along which the sere has proceeded. Certain plants are usually associated with *Andropogon furcatus*, whether it occurs in the hydrosere or in the xerosere. Other secondary species are found only in the hydrosere and others are characteristic of the Bouteloua-Atheropogon subclimax. Some of the plants of more general distribution are:

Anemone cylindrica
Amorpha canescens
Astragalus crassicarpus
Aster laevis
Aster multiflorus
Baptisia bracteata
Galium boreale
Geum triflorum
Heuchera hispida
Helianthus maximilianus
Helianthus scaberrimus
Hedeoma hispida
Koeleria cristata
Liatris scariosa
Lithospermum canescens
Lepachys columnaris
Oxalis violacea
Pentstemon grandiflorus
Phlox pilosa
Poa triflora
Potentilla arguta
Ranunculus ovalis
Rosa pratincola
Senega alba
Solidago canadensis
Solidago nemoralis
Silphium laciniatum
Tradescantia bracteata
Viola pedatifida
Vicia americana
Zizia aurea

Some of the more common secondary species of this association in the development of the hydrosere are:

Anemone canadensis
Carex festucacea
Carex gravida
Castilleja coccinea
Fragaria virginiana
Hypoxis hirsuta
Liatris pycnostachya
Thalictrum dasycarpum
Zygadenuse legans
Zizia cordata

The following are found more often in drier soils on which Bouteloua and Atheropogon are the dominant grasses:

Anemone caroliniana
Aster sericeus
Aster oblongifolius
Castilleja sessiliflora
Liatris punctata
Lithospermum linearifolium
Pentstemon albidus
Psoralea esculenta
Pulsatilla hirsutissima

In this association, repeated burning instead of destroying it and causing its development to be repeated through one or more earlier stages, acts as a stabilizer by preventing the encroach-

ment upon it of the deciduous forest, which always tends to advance and replace the prairie in more favorable situations. Fire is a contributory factor in maintaining dominance only in the ecotone between prairie and deciduous forest. Over the prairie climax region as a whole the determining factor is climate.

University of Michigan

NOTES ON THE ORANGE RUSTS OF RUBUS

E. A. BESSEY

The orange rust of Rubus has been known for more than one hundred years, having been first described by Von Schweinitz (1) in 1822. The discovery reported by Kunkel (2) in 1913 that there is not one orange rust, but two, has led to further study of the question. Much attention has been given to the question of the distribution of these two rusts upon the various species of Rubus and in the different parts of the country. It was at first suggested by Arthur (3) that the short cycle form was more prevalent in the warmer parts of the country, and the long cycle form in the cooler regions. B. O. Dodge (4) has just reported the results of investigations on this point which seem to throw doubt upon the correctness of Arthur's assumption, since both forms are found as far south as North Carolina and as far north as Massachusetts.

For some years I have been making germinations of spores of orange rust specimens sent in from various parts of Michigan in the hope of being able to throw additional light on this question. Both the short cycle form, *Kunkelia nitens* (Schw.) Arth., and the long cycle form, *Gymnoconia interstitialis* (Schl.) Lagh., have been found in the state, the former being recognizable by the fact that its aeciospores function as teliospores and germinate by means of a promycelium, while in the latter form they germinate by a long germ tube.

In 1921 the short cycle rust was found on specimens of Rubus coming from Bay, Hillsdale, McComb, Lapeer and Wayne counties, the long cycle rust being obtained from Ingham and Cass counties in the Lower Peninsula and from Alger county in the Upper Peninsula.

In 1922 the short cycle rust was found in Clinton County a few miles northeast of Lansing, in Eaton County, a few miles west of Lansing, and in southwestern Ohio at Oxford. The long cycle form was found in Ingham, Eaton, Van Buren, Oceana and Washtenaw counties in the Lower Peninsula, and again in Alger County in the Upper Peninsula. It may be noted here that I found the long cycle form in the telial stage in Gogebic County in 1919.

It is interesting to note that there is somewhat of an overlapping of host species for the two species of rust. Thus the short cycle rust was found on the wild black raspberry, *Rubus occidentalis*, last summer at Grand Ledge in Eaton County, while the long cycle rust was found on the same species in East Lansing in Ingham County. At Oxford, Ohio, I found *Rubus allegheniensis* badly rusted with the short cycle form, while the long cycle form was found on the same host in East Lansing, Grand Ledge and at Chatham in Alger County. The short cycle form, only, was found on *Rubus procumbens* (= *R. villosus*). The long cycle form was obtained from cultivated raspberries, one of them certainly being the black raspberry (a form of *R. occidentalis*, probably) while some of the others were on red raspberries, which are probably forms of *R. strigosus*.

Studies of spore sizes were undertaken to verify the results reported by Kunkel (5). When the measurements were confined to living turgid spores which had not lost their color, the short cycle spores averaged $26.9 \times 25.4\ \mu$, the extreme range being $19.4–31.9 \times 18–30.5\ \mu$. The corresponding measurements for the long cycle spores were $29.4 \times 27.8\ \mu$ with the extremes of 21.7 to 37.7×20.3 to $34.8\ \mu$.

Upon drawing a frequency curve to illustrate the distribution of the various lengths and widths of the spores of the two species, the mode of the curve for the short cycle form occurred at about 26 μ for the length and 24 μ for the width, the corresponding figures for the modes of the long cycle form being 28 μ for both length and width. In the long cycle form the curve for spore lengths is somewhat of a skew curve, rising abruptly to the mode and falling more slowly beyond the node, so that the

mean lies considerably beyond the mode. For the width of spores the curve is nearly symmetrical, the mean and mode almost coinciding. In the case of the short cycle rust the curves for width and length are similar, being skew curves with the mean a little above the mode. (See Fig. 3.)

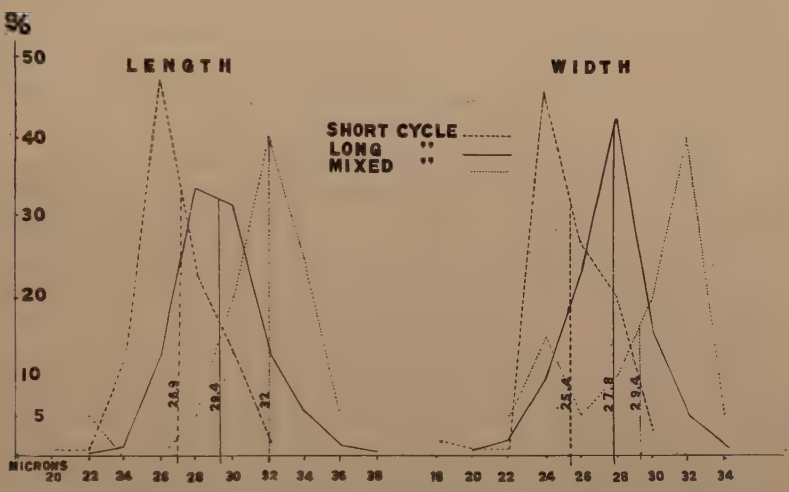


FIG. 3. Graphs showing the distribution of the different lengths and widths of spores of orange rusts on Rubus. Since different numbers of spores were studied for the different rusts, their distribution by sizes has all been reduced to the percentage basis for the sake of comparison. The vertical lines represent the mean size for all the measurements of that particular rust.

-------- = Short cycle rust. —— = Long cycle rust.
.... = Mixed cycle rust.

One very interesting specimen was received on leaves of a cultivated blackberry (species not known) in Charlevoix County. Part of the spores of this germinated by promycelia and part by germ tubes. Unfortunately the material was rather badly dried out so that it was impossible to carry on further experiments than the first germination tests. The mean and mode for the length of spores of this rust were both about 32 μ and for the width the mean was 29.4 μ and the mode was the same as for the length, 32 μ. The curves for these three lots of rusts are

shown in the figure where the curves are all drawn on the percentage basis.

Spores of these rusts when dry or when dead have somewhat smaller dimensions than those given above, because of a shrinkage as the turgor is lost. On the other hand, a spore left on the surface of the water for purposes of germination, swells in the course of two or three days so as to become 1 to 2 μ longer and wider than the fresh spores. The germinated, and thus empty, spores are from .7 to 1.5 μ shorter and narrower on the average than the fresh spores.

Kunkel (5) pointed out that the short cycle rust usually had a brighter yellow color *en masse* when fresh than the long cycle form which is a deeper orange color. In the main, this seemed to be true with the Michigan specimens, except that one lot of short cycle rust was as dark or even darker orange than any long cycle rust material observed.

In attempting to find other distinctions between the spores, so as to make possible a sure distinction between these two rusts when the material was too old to germinate and too much faded to distinguish it by color, I studied the markings on the walls of the spores. The spore walls are marked with very minute dots which are not distinguishable except under high magnifications and with proper illumination. It was noticed in 1921 that the dots on the short cycle spores appeared to be somewhat farther apart than in the long cycle spores. In 1922, therefore, a large number of spores were examined for this purpose. It was found that by focusing down until the plane of greatest diameter was just in focus the dots would appear more or less evenly spaced at the circumference of the cell. The number of dots thus visible was counted and divided by the number of microns in the circumference of the cell. It was found that the average circumference of the spore — since the spores lie with the longer axis horizontal when viewed under the microscope, this means the polar, not the equatorial, circumference — was about 80 μ for the short cycle spore, and 85 μ for the long cycle spore. The number of dots in the circumference varied from 41 to 75, averaging about 60, for the short

cycle form, and from 59 to 88, averaging 72, for the long cycle form. The average distance apart of the dots for the short cycle form is, therefore, about 1.32 μ, and for the long cycle form 1.18 μ. This is found, however, to have some variations, for on the spores of a long cycle rust on *Rubus allegheniensis* collected in East Lansing, the dots averaged 1.7 μ apart, although on other specimens of long cycle rust on the same species of host they were about 1.2 μ apart. On the other hand, one lot of short cycle spores was found where the dots averaged 1.1 and another where they averaged 1.2 μ apart.

As we meet here at Ann Arbor where Professor F. C. Newcombe has been active so long, it is interesting to note that thirty-two years ago he and Professor Galloway almost discovered the existence of a short cycle form in the Rubus rust. In a paper published by Professor Newcombe (6) the drawings of the highly magnified aeciospores show but a single nucleus, while a drawing of a germinated spore made by B. T. Galloway who appended a note to Professor Newcombe's paper, shows very clearly a promycelium as it appears when it becomes partly submerged before it has developed its sporidia. In such a case, in the place of each sporidium there develops a long, very slender germ tube. This is well shown in the drawing by Galloway, a drawing that duplicates many cases observed by me where the promycelium had become partly submerged.

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GROWTH OF *PINUS RESINOSA* AND *PINUS STROBUS**

DOROTHY J. CASHEN

INTRODUCTION

ANNUAL growths of *Pinus resinosa* Ait. and *Pinus strobus* L. vary from year to year in distances between whorls of branches and in width of annual rings. In the summer of 1922, measurements of these growths were made for these two species in six areas near the Biological Station of the University of Michigan on Douglas Lake, Michigan. Such a study is of special value in the northern part of Michigan, where reforestation is the only practical solution for great stretches of land made bare by lumbering and burning.

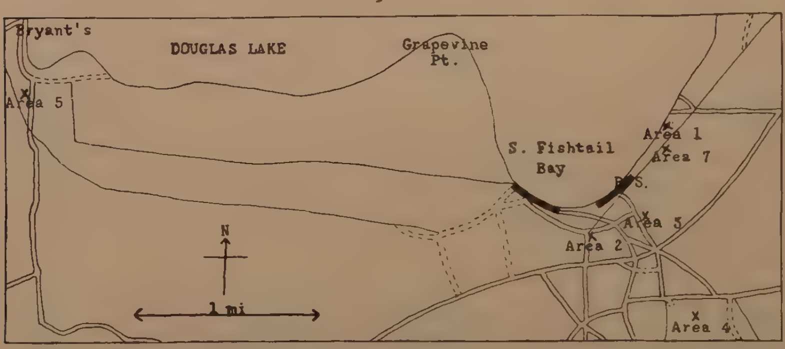
EXPERIMENTAL METHOD

The trees in each area were numbered and plotted on a map. For young trees selected the distances between the yearly whorls of branches were measured and the diameters taken 30 cm. from the ground level with calipers. The diameters of trees too large for measurement by the whorl method were taken in the same manner as those of the younger trees. In each of the six areas taken, five trees of each species were bored one meter from the ground level by means of a standard increment borer. Hydrogen ion tests of soil at various depths in each area were made by the indicator method, as outlined in *Soil Acidity and a Field Method for its Measurements*, by Edgar T. Wherry.

* Contribution from the Botanical Laboratory of the Kansas State Agricultural College, No. 204, and from the University of Michigan Biological Station.

DESCRIPTION OF AREAS

Douglas Lake is situated at an elevation of about 712 feet above sea level in the upper portion of the Lower Peninsula of Michigan, in Cheboygan County, midway between Mackinaw City, Cheboygan, and Charlevoix. About fifty years ago the region was well covered with beech-maple forests, pine forests, and cedar bogs. Since that time lumbering and frequent burns have changed the character of the vegetation to a large extent. In a very few stretches some of the original trees still exist, but in the greater part of the area a typical young aspen association



Map I. Sketch Map showing Positions of Areas in the Vicinity of the Biological Station. A Part of the Base Map of the Douglas Lake Region.

stands. The region presents to the eye an aspect of boundless stretches of young growth with charred stumps and an occasional tall pine from the earlier stand.

The soil is rather sandy and acid with but little humus. There is moderate rainfall of about 31 to 35 inches annually, high summer evaporation, and intense summer sunlight. Aside from the lack of humus due to repeated burns, conditions are favorable to *Pinus resinosa* and *Pinus strobus*.

Seven areas were selected in this region (See Map I). Area I was near the shore, a few feet above lake level; Area II proper,

on a hilltop about one hundred yards southeast of the lake; Area III, on a plateau southeast of the foot of the hill of Area II; Area IV, on a hilltop about one-half mile east of the lake; Area V, on a plateau on the western side of the lake; and Area VI (not indicated on Map), near Big Stone Bay, Lake Michigan. Area VII, just east of Area I, and very similar to it, except for perhaps its greater shade, was studied by G. J. Ikenberry in 1920.

Area I stretches from the southeastern shore of the lake in toward a hill. It is below the slope which is a part of Area VII. Behind this hill and beyond a valley is the higher hill upon which is Area IV. Area I is a little lower in level than Area III. The burn of 1921 came across the northern side of the hill of Area IV, over the hill nearer the lake, down the slope of Area VII, and was stopped just at the "base line" back of Area I. This was a ground fire and destroyed most of the seedling pines which would have furnished an interesting comparison of plateau, slope, and hilltop within a small compass. Such a comparison might be made between the hilltops of Areas II and IV and Areas I and VII.

Close to the lake in Area I are two clusters of pines. With the present type of ice work and wave action on the shore, these will in all probability lose their footholds before many years. For six meters back from the shore there are no aspens (*Populus grandidentata* Michx. and *Populus tremuloides* Michx.), but *Quercus borealis* Michx. f. is abundant. Three large pines, two *Pinus resinosa* and one *Pinus strobus*, standing here, have seeded the entire area. There are a few scattering plants of *Amelanchier canadensis* (L.) Medic., *Rosa sp.* and *Salix sp.* The ground flora consists principally of *Rhus toxicodendron* L., *Arctostaphylos uva-ursa* (L.) Spreng, with some *Pteris aquilina* L., *Poa compressa* L., *Elymus canadensis* L., *Spartina michauxiana* Hitchc., and occasional *Gaultheria procumbens* L., *Maianthemum canadense* Desf., *Aster laevis* L., *Smilacina racemosa* (L.) Desf., *Apocynum cannabinum* L., and two species of Vaccinium, Farther back *Populus grandidentata* and *Populus tremuloides* may be dominant at present, but are distinctly giving way to the pines which are

almost as numerous but not as tall. There are numerous *Betula alba* var. *papyrifera* (Marsh.) Spach. and occasional *Quercus borealis* and *Acer rubrum* L. Of the ground flora, *Pteris aquilina* dominates; the *Vaccinium sp.* are numerous with some *Gaylussacia baccata* (Wang.) C. Koch.; there are occasional plants of *Aster laevis*, *Maianthemum canadense*, *Lactuca canadensis* L., *Gaultheria procumbens*, *Comandra umbellata* (L.) Nutt., *Melampyrum lineare* Lam., and grasses. Farther back the ground flora dwindles down to *Pteris aquilina*, the *Vaccinium sp.*, *Gaultheria procumbens*, *Comandra umbellata*, and an occasional grass. The light in Area I is medium, next to Areas II and IV in intensity. The wind may be a serious factor here. There are several little slopes in Area I which are not large enough to be of great consequence. There is but little humus.

Area II proper is on a hill overlooking the northern point of Burt Lake. The flora of hilltop and slope from which additional trees were measured are similar. All vegetation is more scattering on the hilltop. This area receives the least shade of the seven. The pine trees are the most scattering and the flora is more varied in number of species than any of the others. The soil is sandy with but little humus. *Populus tremuloides* and *Populus grandidentata* are dominant with numerous *Betula alba papyrifera*, *Quercus borealis*, *Prunus pennsylvanica* L., *Prunus virginiana* L., *Salix sp.*, *Amelanchier canadensis*, *Amelanchier spicata* (Lam.) C. Koch., *Acer rubrum*, occasional *Acer pennsylvanicum* L., *Tsuga canadensis* (L.) Carr., *Fagus grandifolia* Ehrh., and *Viburnum acerifolium* L. In addition to the ground plants found in Area I there are *Rubus allegheniensis* Porter and *Rubus idaeus* var. *aculeatissimus* (C. A. Mey.) Regel & Tiling, *Rhus glabra* L., *Polygonatum biflorum* (Walt.) Ell., *Verbascum thapsus* L., *Aster lateriflorus* (L.) Britton., *Lactuca sagittifolia* Ell., *Solidago canadensis* L., *Rumex acetosella* L., *Gnaphalium decurrens* Ives., *Antennaria canadensis* Greene, *Convolvulus spithamaeus* L., *Hieracium venosum* L., *Lepidium virginicum* L., *Fragaria sp.*, *Arabis brachycarpa* (T. & G.) Britton., *Epilobium angustifolium* L., *Hepatica triloba* Chaix., *Prenanthes alba* L., *Polygala paucifolia* Willd., *Lonicera dioica* L., *Trillium grandi-*

florum (Michx.) Salisb., sedges, mosses, and lichens. *Spartina michauxiana* is not found here.

Area III is situated on a level plateau extending back from Douglas Lake. It is about one-eighth of a mile southeast of the lake. The intensity of light is less than in Areas I, II, IV, and VII. There is some humus here although of little depth. A fire has not occurred here for some twenty years. The dominancy of *Populus tremuloides* and *Populus grandidentata* is disappearing as it is in Area I. There are numerous *Betula alba papyrifera*, and several *Acer rubrum* and *Quercus borealis*. The pines are frequently in groups. There are a few large ones which seed this particular region. With the exception of *Spartina michauxiana* and *Rhus toxicodendron* and with the addition of *Rubus allegheniensis*, *Solidago hispida* Muhl., *Lycopodium obscurum* var. *dendroideum* (Michx.) D. C. Eaton., *Rhus glabra*, *Apocynum androsaemifolium* L., *Antennaria canadensis*, *Gnaphalium decurrens*, and *Aralia nudicaulis* L., the ground flora of Area III is not radically different from that of Area I. Beneath the *Pteris aquilina* are mostly bare stretches of ground although there are patches of *Maianthemum*, *Gaultheria*, *Lycopodium*, and mosses.

Area IV is on a hilltop about one-half mile east of the lake. The exposure to light due to scattering vegetation is about the same as in Area II. Vegetation of the herbaceous order is, if anything, more sparse. Available moisture and soil quality are about the same. The flora is similar to that in Area II although there are fewer species here. A somewhat serious ground fire occurred in 1921. On the northeast portion of this hilltop the burn was thorough. No young seedling pines are to be found here; there remain only charred stumps, young aspens, and *Pteris aquilina* growing with many of the ground plants mentioned in the description of Area II. On the southern portion of this hill the fire was not a clean one, although some parts of the ground are still devoid of vegetation.

Area V is a little south of Bryant's Hotel in good soil, formerly covered by beech-maple woods, but now mostly covered by the aspen association. The pine trees measured were in two

groups with the remainder of the area unpopulated except for young aspens and birches. Part of this distribution is due to clearings. No *Pinus resinosa* are present. In Group A the lower plants are seriously affected by a lack of light. Area V is the darkest of the seven areas. The flora of Group A is very similar to that of Area I except that the shade is so dense that the number both of species and of individual plants is smaller, and that the dominance of the Populus association is positive. There are a few elms present. Toward the center of the group there are only stretches of dead leaves beneath the *Pteris aquilina*. In Group B *Acer rubrum* dominates although there may be an occasional larger oak. *Pteris aquilina* and *Rhus glabra* dominate the ground flora. Two large pines have seeded both groups.

Area VI is close to the shore of Lake Michigan at the north end of Big Stone Bay. It is different in character from those nearer Douglas Lake, in that it is a captured dune area. It stands at the edge of a virgin forest of *Tsuga canadensis*, *Picea canadensis* (Mill.) BSP., *Picea mariana* (Mill.) BSP., *Thuja occidentalis* L., and *Abies balsamea* (L.) Mill. It is the least disturbed of the seven areas. Here *Picea canadensis*, *Picea mariana*, *Tsuga canadensis*, and *Abies balsamea* are dominant; *Pinus strobus*, rather abundant; *Pinus resinosa*, *Thuja occidentalis*, and *Larix laracina* (Du Roi) Koch., occasional. The ground flora is somewhat sparse. In spaces where trees are absent, *Juniperus communis* var. *depressa* Pursh., *Rosa carolina* L., *Pteris aquilina*, and *Ledum groenlandicum* Oeder. are scattering, together with *Mitchella repens*, L., *Comandra umbellata*, *Polygonatum biflorum*, *Maianthemum canadense*, *Fragaria sp.*, *Aster sp.*, mosses and lichens. Some humus is present in this area. Next to Group A, of Area V, this area is the darkest. Wind is a more serious factor here than in any of the other areas.

DISCUSSION

The data with regard to the areas, the number and percentages of trees, rates of growth, and other aspects of this study, have been compiled in tabular form.

TABLE I

SIZES OF AREAS STUDIED EXPRESSED IN METERS

Area	I	II	III	IV	V	VI	VII
Length	60	168	82	112	60	29	?
Width	25	124	48	90	25	25	?

Table II gives the percentages of *Pinus resinosa* and *Pinus strobus* in plots which are of approximately the same size, 60×25 meters. Plots IIa, IIb, IIc, IIIa and IVa are of the prescribed size in their respective areas, which include more territory. It will be noticed that Areas I and III are the most densely populated with pines, and Areas II and IV are the least.

TABLE II

NUMBER OF PINES IN PLOTS 60 BY 25 METERS AND PERCENTAGES OF *PINUS RESINOSA* AND *PINUS STROBUS*

Area	I	IIa	IIb	IIc	IIIa	IVa	V
Small trees (number)	179	15	8	5	81	16	61
Pinus resinosa (per cent)	*21.8*	*33.3*	*87.5*	*40*	*21*	*81.3*	*0*
Pinus strobus (per cent)	*78.2*	*66.7*	*12.5*	*60*	*79*	*18.7*	*100*
Large trees (number)	3	1	3	6	19	4	2
Pinus resinosa (per cent)	*0*	*100*	*100*	*100*	*63*	*100*	*0*
Pinus strobus (per cent)	*100*	*0*	*0*	*0*	*37*	*0*	*100*
Total trees in area (number)	182	16	11	11	100	20	67*
Pinus resinosa (per cent)	*21.4*	*37.5*	*90.9*	*72.7*	*29*	*85*	*0*
Pinus strobus (per cent)	*78.6*	*62.5*	*9.1*	*27.3*	*71*	*15*	*100*

*Including four trees so nearly dead that no measurements from them were used.

Table III gives the total percentages of trees studied in each area irrespective of size. The large trees listed were ones too

large to be easily measured by the whorl method. In many cases they are trees which have escaped past burns and are seeding the areas in question. In Areas II, III, and IV some of the large trees were bored. It is interesting to note that except in the case of Area III, the species which has the largest number of large trees has also the largest number of trees small enough to be measured by the whorl method. The relationship here is probably that of seeding.

TABLE III

NUMBER OF PINE TREES IN AREAS AND PERCENTAGES OF *PINUS RESINOSA* AND *PINUS STROBUS*

Area	I	II	III	IV	V	VI	VII
Small trees (number)	179	49	107	35	61	41	127
Pinus resinosa (number)	39	24	24	25	0	5	29
(per cent)	*21.8*	*49*	*22.4*	*71.4*	*0*	*12.2*	*22.8*
Pinus strobus (number)	140	25	83	10	61	36	98
(per cent)	*78.2*	*51.*	*77.6*	*28.6*	*100*	*87.8*	*77.2*
Large trees (number)	3	19	25	32	2	32	?
Pinus resinosa (number)	0	17	14	29	0	15	
(per cent)	*0*	*89*	*56*	*90.6*	*0*	*46.9*	
Pinus strobus (number)	3	2	11	3	2	17	
(per cent)	*100*	*11*	*44*	*9.4*	*100*	*53.1*	
Total trees in area	182	68	132	67	67*	73	
Pinus resinosa (number)	39	41	38	54	0	20	
(per cent)	*21.4*	*60.3*	*28.8*	*80.6*	*0*	*27.4*	
Pinus strobus (number)	143	27	94	13	67	53	
(per cent)	*78.6*	*39.7*	*71.2*	*19.4*	*100*	*72.6*	?

* Including four trees so nearly dead that no measurements from them were used.

Table IV shows little relationship in the inceptions of *Pinus strobus* and *Pinus resinosa,* except that between 1904 and 1911 there was the largest number of new trees starting. The fact that there are no new trees in recent years in Areas V and VI and that the young trees in Area V are dying rapidly might be

due to lack of light. The burn in Area IV accounts for the absence of young trees there.

TABLE IV

Inceptions of Pine Trees in Areas

Area	I	I	II	II	III	III	IV	IV	V	VI	VI	VII	VII
Species	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus resinosa
1922	0	0	0	0	0	0	0	0	0	0	0		
1921	0	0	0	0	0	0	0	0	0	0	0		
1920	1	1	0	2	2	0	0	0	0	0	0	0	0
1919	0	0	0	3	0	0	0	2	0	0	0	1	0
1918	2	1	0	0	2	0	0	0	0	0	0	1	2
1917	1	0	0	0	0	0	0	1	0	1	0	4	2
1916	1	0	0	0	0	0	0	1	1	0	0	3	1
1915	3	0	0	0	0	0	0	1	0	0	1	4	4
1914	4	1	0	0	1	1	0	1	0	1	0	9	5
1913	5	2	0	1	3	2	0	0	1	1	0	11	5
1912	5	3	0	2	3	2	0	0	1	1	0	18	1
1911	8	4	0	0	4	3	1	0	5	3	0	11	4
1910	16	5	4	0	6	0	0	1	5	3	0	8	3
1909	10	3	4	2	5	3	1	3	5	3	0	12	1
1908	16	4	2	0	10	0	0	1	6	5	0	10	0
1907	19	5	1	2	16	0	1	1	8	3	1	3	0
1906	17	3	5	1	13	3	1	1	7	3	0	1	0
1905	14	1	2	2	5	1	1	0	8	6	0	1	1
1904	7	4	5	1	8	1	0	7	6	0	0	0	
1903	7	..	1	3	3	2	2	1	4	0	0	1	
1902	0	..	0	3	1	5	0	0	0	1	0		
1901	2	..	1	0	0	0	1	3	1	0	1		
1900	1	..	..	1	0	1	0	0	0	2	0		
1899	0	..	..	0	1	..	1	1	0	0	0		
1898	2	..	..	0	..	..	1	..	0	2	0		
1897	..	..	..	1	..	..	..	..	1	0	0		
1896	..	..	..	..	..	..	..	..	..	0	0		
1895	..	..	..	..	..	..	..	..	..	0	1		
1894	..	..	..	..	..	..	..	..	..	0	1		
1893	..	..	..	..	..	..	..	..	..	0			
1892	..	..	..	..	..	..	..	..	..	0			
1891	..	..	..	..	..	..	..	..	..	0			
1890	..	..	..	..	..	..	..	..	..	0			
1889	..	..	..	..	..	..	..	..	..	1			

Table V gives the growths between whorls of branches averaged for each species in each area, the average growth for the fastest growing tree in the area, and the average growth for the slowest growing tree.

TABLE V

Average Growths in Centimeters

(For number of trees included, see Table III)

Area	I	II	III	IV	V	VI	VII
Average annual growth:							
Pinus resinosa	9.8	13.3	12.1	10.7	....	9.5	12.3
Pinus strobus	10.0	12.6	11.5	9.8	7.6	8.6	11.0
Average growths of the fastest growing tree:							
Pinus resinosa	18.3	19.2	17.5	19.6	....	11.6	17.6
Pinus strobus	22.8	18.9	18.8	17.9	14.9	15.4	28.0
Average growth of the slowest growing tree:							
Pinus resinosa	4.1	5.9	6.2	4.6	....	7.2	6.3
Pinus strobus	2.6	4.6	3.2	5.5	2.2	2.1	3.4

On account of natural pruning, it was sometimes necessary to estimate how many years the growth nearest the ground represented. Where scars of branches existed, no difficulty occurred. In Areas I and II, *Pinus strobus* often makes two whorls of branches a year; the first growth between whorls is generally short varying from 0.5 to 2 cm.; the second growth is long, quite often 20 or 30 cm. in length. This does not occur in *Pinus resinosa* and only seldom in *Pinus strobus* in the other areas. In older wood it is difficult to say whether two whorls appearing just as described belong to two years or one. As a rule if such a case occurs once in more recent years, it is found to occur at intervals during the tree's growth.

In every area except in Area I, *Pinus resinosa* leads in longitudinal growth, and even in Area I is exceeded by only

.2 cm. The highest average growths of both species occurred in Area II, while the lowest average growth of *Pinus strobus* was in Area V, where *Pinus resinosa* was absent. It is interesting to note that *Pinus strobus* has the most variable growth, varying from 2.1 cm., the lowest minimum of both species, to 22.8 cm., the highest maximum of both species. These minimum and maximum variations seem related to the individual trees concerned rather than to any local conditions. On the contrary, the variations of the average annual growths of both species seem to be due to the locality, since the curves for the two species are essentially similar.

Table VI is a comparison of annual increments, as measured from the borings, with the annual longitudinal growths. In Areas I and V the trees bored were also measured by the whorl method, in order that a comparison might be made. In Areas II, III and IV some of the trees bored were too large to be measured by the whorl method. Since the comparison in measurements in Area V is very similar to that in Area I, only that for Area I is given.

As can be seen from the table, the annual increments vary far less than the distances between whorls of branches. It will be seen that the age as counted from the annual rings differs hardly at all from the age as counted from the whorls of branches for the same tree. From these measurements there seems to be no close correlation between annual longitudinal growth and annual growth in thickness, although there is a certain relationship between total height and total diameter.

TABLE VI A

Comparisons of Annual Increments of Pinus strobus (I) with Annual Longitudinal Growths (L) in Area I, Expressed in Centimeters

No. of Tree	69		95		99		100		148	
	L	I	L	I	L	I	L	I	L	I
Age	20	20	20	19	18	18	19	16	22	20
1922	25.5	.10	32.5	.10	29.0	.10	25.0	.10	20.5	.10
1921	45.0	.10	64.5	.10	43.0	.10	34.5	.10	7.0	.50
1920	22.4	.10	35.7	.10	33.5	.10	21.0	.10	29.5	.50
1919	23.5	.10	17.7	.10	15.3	.15	32.0	.10	34.8	.10
1918	38.7	.10	1.0	.10	42.0	.15	26.0	.10	27.0	.10
1917	50.0	.10	38.5	.12	49.5	.20	38.0	.10	48.2	.10
1916	17.0	.15	1.5	.10	58.0	.30	22.5	.10	18.0	.15
1915	39.5	.15	51.7	.10	34.2	.20	40.2	.10	3.5	.15
1914	13.8	.20	23.0	.10	10.0	.20	24.5	.10	44.1	.20
1913	9.0	.20	46.0	.10	3.5	.25	10.0	.10	41.6	.15
1912	15.0	.10	26.0	.10	26.0	.15	15.5	.10	29.3	.10
1911	16.0	.10	14.0	.10	14.5	.20	10.7	.10	19.3	.15
1910	12.5	.10	16.0	.13	11.5	.10	10.2	.20	8.5	.05
1909	8.0	.15	13.0	.10	8.0	.10	7.3	.10	4.8	.10
1908	14.0	.15	7.0	.15	7.0	.10	4.5	.10	10.0	.15
1907	13.0	.10	7.0	.15	10.0	.05	3.5	.10	10.0	.10
1906	9.0	.10	6.8	.10	8.0	.10	3.3	..	3.0	.10
1905	5.0	.10	5.5	.10	8.0	.10	5.5	..	3.3	.10
1904	3.5	.10	6.5	.10	.....	..	5.0	..	4.2	.10
1903	5.0	.10	6.5	..	.....	..	....	..	3.5	.10
1902	.....	..	.....	..	.....	..	....	..	5.0	
1901	.....	..	.....	..	.....	..	....	..	6.0	
1900	.....	..	.....	..	.....	..	....	..	....	
Diam...	.....	6.5	.....	5.3	.....	6.1	..	4.4	....	4.8
Height..	385.4	..	420.4	..	411.0	..	339.2	..	381.1	
Height / Diam.	59.3		79.3		67.3		77.1		79.4	

TABLE VI B

COMPARISONS OF ANNUAL INCREMENTS OF PINUS RESINOSA (I) WITH ANNUAL LONGITUDINAL GROWTHS (L) IN AREA I, EXPRESSED IN CENTIMETERS

No. of Tree	91		107		115		144		150	
	L	I	L	I	L	I	L	I	L	I
Age	19	18	19	16	17	17	16	16	14	13
1922	13.0	.10	15.5	.05	19.0	.10	30.0	.10	25.0	.10
1921	36.0	.10	15.0	.10	14.8	.05	38.5	.05	20.0	.10
1920	16.0	.05	13.3	.05	17.0	.05	20.0	.10	11.0	.10
1919	21.0	.10	13.5	.05	17.4	.05	28.3	.20	10.5	.10
1918	11.0	.10	9.3	.10	18.0	.10	22.0	.10	28.3	.05
1917	19.3	.10	21.5	.05	19.7	.05	20.5	.10	18.8	.10
1916	30.0	.10	28.0	.15	21.7	.05	30.1	.10	23.5	.10
1915	24.0	.20	5.5	.10	14.0	.10	26.8	.10	24.5	.10
1914	12.1	.15	13.5	.15	5.5	.10	18.5	.10	15.0	.15
1913	11.2	.10	14.6	.10	12.0	.10	9.0	.10	18.0	.05
1912	15.0	.10	8.7	.05	9.5	.05	13.0	.10	7.8	.05
1911	13.5	.10	12.5	.05	9.0	.10	12.5	.20	11.0	.10
1910	8.0	.10	9.5	.05	6.5	.05	5.0	.20	13.0	.10
1909	16.6	.10	5.0	.05	10.0	.10	3.0	.10	7.0	
1908	6.0	.10	5.0	.05	5.2	.05	7.0	.10		
1907	4.8	.10	8.8	.05	5.0	.10	8.0	.10		
1906	4.0	.10	5.7	..	7.0	.10				
1905	6.5	.10	3.5							
1904	6.5	..	8.5							
1903										
1902										
1901										
1900										
Diam...	.....	4.5	.....	3.0	.....	2.6	....	4.2	....	2.9
Height..	274.5	..	216.9	..	211.3	..	292.2	..	233.4	
Height / Diam.	61.0		72.3		81.3		69.5		80.5	

Table VII gives the average annual increments, as estimated from the five trees of each species bored in each of the first five areas.

TABLE VII

Average Annual Increments of Certain Trees Expressed in Centimeters

Five trees selected in each Area

Area I

Pinus resinosa (Average annual increment, .09)

Number of tree	91	107	115	144	150
Average annual increment	.11	.08	.08	.12	.09
Maximum annual increment	.20	.15	.10	.20	.15
Minimum annual increment	.05	.05	.05	.05	.05

Pinus strobus (Average annual increment, .13)

Number of tree	69	95	99	100	148
Average annual increment	.12	.11	.15	.11	.11
Maximum annual increment	.20	.15	.30	.20	.20
Minimum annual increment	.10	.10	.05	.10	.05

Area II

Pinus resinosa (Average annual increment, .12)

Number of tree	12	23	24	31	47
Average annual increment	.12	.11	.09	.13	.12
Maximum annual increment	.40	.25	.20	.30	.25
Minimum annual increment	.05	.05	.05	.05	.05

Pinus strobus (Average annual increment, .10)

Number of tree	10	16	21	59	60
Average annual increment	.08	.14	.09	.09	.08
Maximum annual increment	.15	.50	.20	.10	.10
Minimum annual increment	.05	.03	.05	.05	.05

TABLE VII — *Continued*

AREA III

Pinus resinosa (Average annual increment, .09)					
Number of tree	5	12	13	27	31
Average annual increment	.09	.07	.09	.09	.10
Maximum annual increment	.15	.20	.15	.15	.20
Minimum annual increment	.03	.02	.05	.03	.05

Pinus strobus (Average annual increment, .09)					
Number of tree	3	7	18	20	35
Average annual increment	.10	.08	.09	.09	.10
Maximum annual increment	.20	.10	.15	.20	.25
Minimum annual increment	.05	.03	.05	.03	.05

AREA IV

Pinus resinosa (Average annual increment, .10)					
Number of tree	5	7	8	10	13
Average annual increment	.10	.15	.10	.09	.09
Maximum annual increment	.20	.20	.20	.20	.20
Minimum annual increment	.03	.05	.05	.03	.05

Pinus strobus (Average annual increment, .09)					
Number of tree	9	11	12	25	28
Average annual increment	.10	.10	.08	.08	.07
Maximum annual increment	.15	.20	.10	.10	.15
Minimum annual increment	.05	.05	.03	.03	.05

AREA V

Pinus strobus (Average annual increment, .07)					
Number of tree	30	31	37	39	42
Average annual increment	.09	.08	.05	.06	.05
Maximum annual increment	.15	.15	.10	.10	.10
Minimum annual increment	.05	.05	.05	.05	.03

It may be noted that the variations in average annual increments for the areas are similar to those in longitudinal growth measurements given in Table V. *Pinus resinosa* leads except in Area I. Area V in both cases shows the least growth in *Pinus strobus*.

TABLE VIII

AVERAGE ANNUAL INCREMENTS FOR AREAS BASED UPON DIAMETERS MEASURED 30 CM. FROM THE GROUND, EXPRESSED IN CENTIMETERS

(*Age of trees determined by whorl method*)

(For number of trees included, see Table III)

Area	I		II		III		IV		V	VI	
Species	Pinus resinosa	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus strobus	Pinus resinosa	Pinus strobus
Average annual increment	.10	.17	.32	.23	.23	.19	.22	.16	.11	.18	.13

From Table VIII it may be seen that the annual increments based on the diameters 30 cm. from ground level approximate those obtained from borings. The former show an even closer relationship to the longitudinal growth measurements than do the latter. From comparisons made with Tables V, VII, and VIII, it appears that conditions favoring the greatest longitudinal growth do also in the long run favor the largest diametric growth.

Table IX shows some correlation between yearly average longitudinal growths in the different areas. It may be seen that the growths in the years 1915 to 1918 were fairly good in all of the areas and that at such a time there is a closer correlation between the greatest growths of both species in all areas than in the normal run of yearly growths. The data for temperature [1] and precipitation at the Biological Station is too limited

[1] For meteorological records, the reader is referred to U.S. Weather Bureau in coöperation with the Michigan State Weather Service; Gates, F. C., and Ruth E. Hurd: Meteorological Data, Douglas Lake, Michigan, 1912–1918; and to subsequent papers in the Michigan Academy of Science Reports.

TABLE IX

AVERAGE ANNUAL LONGITUDINAL GROWTHS EXPRESSED IN CENTIMETERS

(For number of trees included, see Table III.)

Areas	I		II		III		IV		V	VI		VII	
Species	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus strobus	Pinus resinosa	Pinus strobus	Pinus resinosa
1922	14.4	12.4	23.2	15.6	20.3	16.5	17.2	12.9	10.6	13.7	15.5		
1921	19.0	14.4	31.3	19.2	22.6	19.4	17.4	11.4	11.6	13.4	11.1		
1920	9.1	8.9	14.9	16.1	11.7	8.9	11.3	10.6	7.7	9.3	8.7	9.7	10.8
1919	12.8	12.6	15.2	17.7	15.6	15.5	11.2	11.0	8.0	8.7	11.5	13.8	15.2
1918	10.1	9.9	12.3	11.3	13.8	11.4	10.1	9.8	7.9	8.2	10.8	12.5	14.2
1917	15.8	11.6	16.1	14.3	15.3	11.2	12.6	12.5	9.6	11.1	11.9	14.9	13.9
1916	11.9	13.5	12.2	21.1	12.3	15.5	7.7	12.9	7.9	9.2	15.7	15.2	14.9
1915	11.8	10.4	13.6	17.9	11.8	16.5	11.9	9.5	9.8	9.8	14.9	9.6	11.0
1914	8.7	8.3	10.9	15.7	10.5	13.9	7.8	8.6	8.4	5.9	8.1	9.3	10.0
1913	7.1	7.4	9.4	10.1	9.3	10.6	5.9	10.0	6.9	5.9	7.8	9.3	9.9
1912	7.7	7.7	10.9	13.7	8.6	11.0	8.5	11.1	6.6	7.4	9.8	8.1	9.3
1911	6.9	7.9	9.3	11.1	6.9	9.9	8.7	11.5	5.9	8.1	7.4	8.1	9.2
1910	6.0	6.6	8.2	11.3	5.7	7.3	7.3	9.1	5.1	6.9	8.5	7.4	9.0
1909	5.2	6.2	6.2	11.1	5.4	8.3	7.7	9.5	4.9	5.7	5.6	7.6	7.9
1908	5.3	6.6	5.7	8.9	5.6	8.4	8.2	12.8	5.2	6.6	5.2	8.4	14.0
1907	5.3	6.6	6.1	5.8	5.6	7.7	5.5	11.9	4.8	6.0	7.1	10.5	7.3
1906	4.6	7.3	6.3	10.6	5.7	7.3	10.2	11.3	5.9	7.8	3.9	7.3	7.3
1905	4.4	6.3	4.8	9.9	5.1	7.6	7.4	8.1	5.6	9.0	8.5	18.3	7.3
1904	5.1	7.3	5.3	11.1	6.6	10.1	8.2	8.1	5.9	7.0	11.2	8.0	
1903	5.7	..	5.8	8.1	7.0	9.4	7.9	10.3	6.6	10.8	7.7	11.0	
1902	4.4	..	7.0	7.8	11.0	8.1	9.8	8.1	5.5	9.1	7.8		
1901	6.4	..	5.5	15.9	18.0	13.3	10.3	8.5	5.2	7.8	8.7		
1900	5.3	..	..	7.0	8.0	5.0	7.0	11.0	3.3	6.2	9.2		
1899	2.3	..	..	6.0	9.0	..	6.9	11.0	3.8	5.1	9.7		
1898	3.3	..	..	7.0	..	..	6.3	..	4.2	6.1	3.3		
1897	..	..	..	7.0	..	..	..	..	3.5	6.5	6.3		
1896	..	..	..	..	..	..	..	..	..	2.5	6.3		
1895	..	..	..	..	..	..	..	..	..	5.2	7.2		
1894	..	..	..	..	..	..	..	..	..	4.0	7.3		
1893	..	..	..	..	..	..	..	..	..	11.2			
1892	..	..	..	..	..	..	..	..	..	11.5			
1891	..	..	..	..	..	..	..	..	..	9.5			
1890	..	..	..	..	..	..	..	..	..	9.0			
1889	..	..	..	..	..	..	..	..	..	5.5			

to be of value for comparison here. No correlation seems evident between the greatest yearly average growths and the records for Mackinaw City or Cheboygan. It is evident, however, that although local conditions are important there are some yearly variations which are common to all areas in the general region.

The hydrogen ion determinations for Table X were formulated with Dr. Minna Jewell's standard color solutions made from buffer tablets furnished by the Pyrolectic Co.

TABLE X

HYDROGEN ION DETERMINATIONS OF SOIL

Level below surface in inches	3	6	12	24
Area I:				
Near lake	4.4	4.0	4.6	5.8
Away from lake	4.4	4.0	4.4	4.6
Area II:				
On slope	5.6	4.0	4.4	4.6
On hilltop	5.6	4.0	4.4	4.4
Area III	4.4	4.0	4.4	4.4
Area IV	4.4	4.0	4.4	4.4
Area V	...	4.6	6.0	6.0
Area VI	...	6.6		

SUMMARY

1. A study of the growth of pines was carried on at the University of Michigan Biological Station on Douglas Lake, Cheboygan Co., Michigan, during the summer of 1922. Knowledge of this sort is of special importance in reforestation, which is the practical solution for much of the northern areas left barren by lumbering and burning.

2. The density and species of pines in the areas studied is directly related to seeding. The areas most densely populated are ones of medium shade and moisture.

3. The number of yearly pine inceptions varies. The years of greatest inceptions in the recent past have been from 1904 to 1911. There are inceptions for almost every year in each area except for such times as there were burns, and for certain odd years in all the areas.

4. Ordinarily in this sandy region *Pinus resinosa* leads in both longitudinal and diametric growth. The conditions favoring the greatest growths of both species are apparently the same, as well as are those favoring the least. The growth of *Pinus strobus* is more variable than that of *Pinus resinosa.*

5. The conditions influencing the actual growths of *Pinus resinosa* and *Pinus strobus* are largely local. Total precipitation and temperature do not closely correlate with the growth, although in years of general favorable conditions the growths in all areas have been good. Other factors include light, humidity, soil moisture, and slope. Soil acidity is one of the least important.

6. From this study one might expect that, on burnt-over sandy land in the northern part of the Lower Peninsula of Michigan, the annual longitudinal growth of *Pinus strobus* will be from *2.1*–(**10.2**)–*28.0* cm., and that of *Pinus resinosa*, from *4.1*–(**14.2**)–*19.6* cm.

Kansas State Agricultural College
Manhattan, Kansas

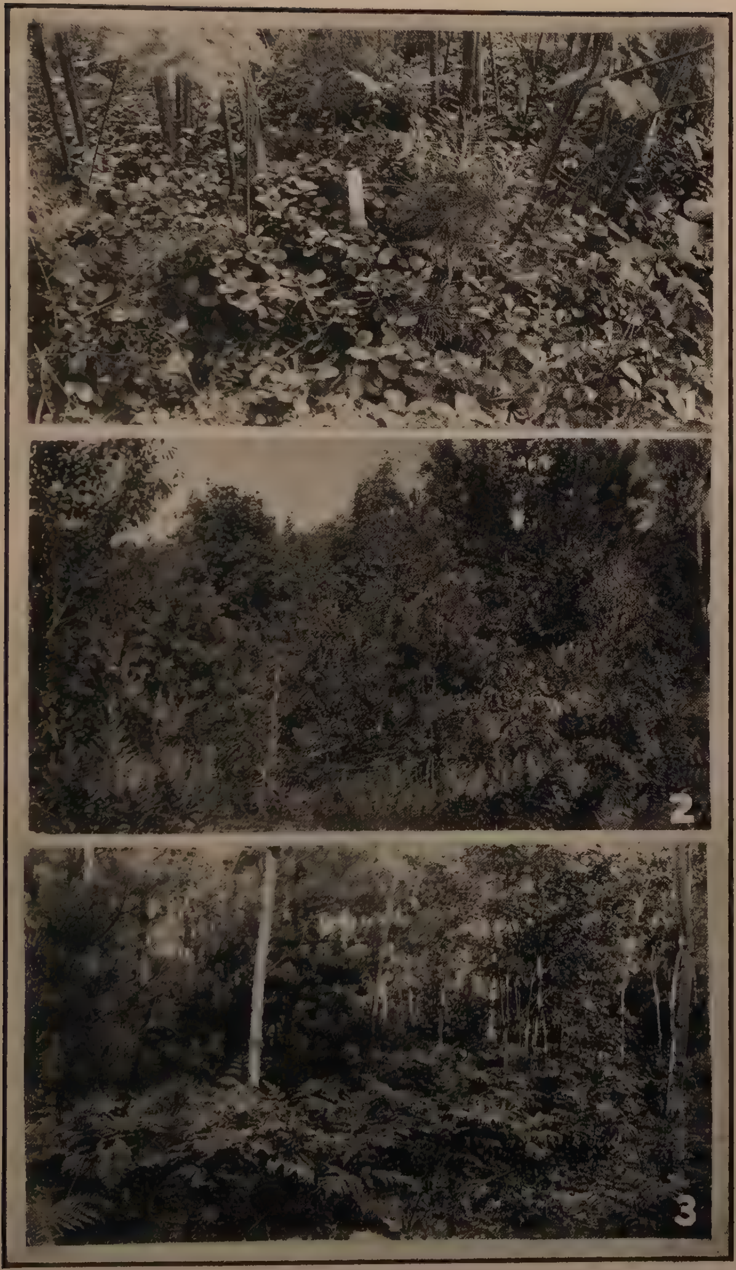
EXPLANATION OF PLATE XV

FIG. 1. A Young Pine Seedling near Atmometer in Area VII (Photograph by F. C. Gates)

FIG. 2. Young Pines on Slope of Area II (Photograph by Ruth H. West)

FIG. 3. Groups of PINUS RESINOSA and PINUS STROBUS in Area III (Photograph by F. C. Gates)

PLATE XV



NOTES ON THE MICHIGAN FLORA

PART VI *

OLIVER ATKINS FARWELL

THE year 1922, being unusually dry and not overly hot, was an exceptionally good year for field work. Advantage of this condition was eagerly seized upon and explorations were extended to a wider range than heretofore, covering nine counties or parts of them; viz., St. Clair, Lapeer, Genesee, Macomb, Oakland, Livingston, Washtenaw, Wayne and Monroe, including the basins of the Clinton, Saginaw, Rouge, Huron and Raisin rivers. Mr. Bruno Gladewitz of Detroit was an invariable and congenial companion on these excursions; he is an enthusiastic investigator, an astute botanist, and as familiar with the flora of southeastern Michigan as anyone.

Mr. Billington went with us, on May 23, on a hunt for Isopyrum near Farmington, but the plant was not detected. Billington, however, found the long beech fern, *Thelypteris Phegopteris;* there were only a half-dozen fronds or so and most of them were not then fully unrolled; this station in Oakland Co. is very far south for the species. At Gibralter, Wayne Co., on May 31, we found the Ohio buckeye in full bloom. We saw but one tree with a trunk diameter of eighteen inches or more. It was near the river front on an abandoned lot in the heart of the town; but whether it was one of the native trees that civilization had failed to remove, or whether it had been planted there in the dim past, remains an unsolved problem.

On June 14, in the southwest corner of Lapeer Co., we found a large clump of *Phaca neglecta* in prime condition; the flowers

* For Parts I, II, and III, see *Michigan Academy of Science, Annual Reports*, 20: 161–195, 21: 345–371, and 22: 117–185, respectively; for Parts IV and V, see *Papers*, 1: 85–100 and 2: 11–46.

were of a perfect lemon-yellow, probably a color form, as Torrey & Gray in their original description emphasize the fact that the flowers are pure white, as do subsequent authors. The old, withered flowers were white and the fresh flowers become white during the course of drying and pressing to such an extent that little of the original yellow color is discernible. On July 5, we found near Newport, Monroe Co., a vine wide-spread over Crataegi, without sign of flowers or developing fruit, which probably was *Vitis cordifolia.* At the same place we found *Rosa setigera* climbing over Crataegi to a height of about 12 feet. A week later at Hamburg, Livingston Co., we found *Rhus radicans* along the roadside forming a dense hedge many yards in length and 2 or 3 deep; the hedge was 6 or 7 feet high and composed of stout shrubs with the habit of *R. glabra* and *R. typhina.* A strange rose was abundant along the roadsides; it proved to be *Rosa villosa*, which is a new introduction. The stems were stout, very thorny and 6 or 8 feet in height.

At La Salle in Monroe Co., July 26, we found a slender pinweed which proved to be *Lechea Leggettii*, a new acquisition for Michigan. On August 2, at Utica, Macomb Co., we found a large clump of *Tripsacum dactyloides.* This is the second station in Michigan for the sesame grass. A week later between Ypsilanti and Ann Arbor we found a small vetch, *Vicia gracilis;* it had neither flowers nor fruit, but it exactly matched specimens of this species from Europe now in the herbarium of Parke, Davis & Co. Also, a wild mustard was rather common in this region which we could not at the time place. It is the plant known as *Erucastrum Gallicum.* Both of these, so far as we are aware, are new to North America. Here also we found *Panicum virgatum* var. *Cubense.* At Oxford, Oakland Co., October 4, we found a colony of *Helianthus Dalyi.* It covered a piece of sandy ground of perhaps 40 or 50 square feet. It agrees in every respect with the description and illustration in Britton & Brown's *Illustrated Flora,* but there were a few plants, perhaps not over 2 per cent of the colony, that were taller, about 3 feet, and had 5 or 6 long peduncled heads, one from each of the uppermost leaves, a transition towards *H. Maximilliani*, of which *H. Dalyi*

is but a dwarf, one-flowered variety, as I have indicated in an earlier paper. Here, also, Gladewitz found a single specimen of *Croton glandulosum* var. *septentrionalis*. A week later at Lakeville we found an unknown thistle which turned out to be *Carduus acanthoides*, It was well scattered but not abundant and has been at this location for 10 or 12 years.

In what follows, where the year and the name of the collector are not given, it is to be understood that Farwell and Gladewitz made the collections for the year 1922.

THELYPTERIS PHEGOPTERIS (L.) Slosson. In rich woods near Farmington, Wayne Co.; scarce. Billington, Farwell and Gladewitz, No. 6144, May 23.

WOODWARDIA VIRGINICA (L.) Sm. f. **fertilis,** n. f. A condition of the sterile frond in which some of the upper pinnules have a few scattered sori. In swampy woods near Lakeville. The plants growing in the shade are larger, deeper green and less coriaceous than those of the sunny, open places. Billington, Farwell and Gladewitz, No. 6445½, Oct. 11.

FILIX MARGINALIS (L.) Farwell. Abundant in a cedar swamp near Oxford. No. 6423, Oct. 4.

BOTRYCHIUM DISSECTUM Spreng. In open woods or in more grassy situations along their borders. St. Clair Co., No. 6404, Sept. 27 and No. 6469, Nov. 5. Associated with this we found var. *obliquum* (Muhl.) Clute, No. 6405, Sept. 27 and No. 6470, Nov. 5; and var. *elongatum* (Gilb. & Harb.) Farwell, No. 6468, Nov. 5. In another open woods about a mile distant and separated by cultivated farms we found the var. *obliquum*, No. 6475, Nov. 5; also var. **tenuifolium** (Underw.), n. comb., (*B. tenuifolium* Underwood, *Bull. Tor. Bot. Club*, XXX [1903]: 52), No. 6476, Nov. 5 and var. **Oneidense** (Gilbert), n. comb., (*B. obliquum* var. *Oneidense* (Gilbert) Waters in Gray's *New Manual* [1908], p. 49), No. 6477, Nov. 5. Of these the var. *Oneidense* was the only form found bearing a fertile panicle; the tomentose but undeveloped bud of the fertile segment was observable near the base of the stalk in the varieties *tenuifolium* and *obliquum*. There were many intermediate forms bearing characteristic segments of one or another of the varieties, so that it was difficult

to place them satisfactorily in any one variety. With a complete series from typical *tenuifolium* to typical *obliquum* before one, it would seem rather foolish to try to split this variety into a number of named forms; on the other hand, without such intermediate forms certain extremes would seem to be worth recognition. It is a question in my mind if some of these forms do not represent different years in the age of the individual, different stages in the developing plant rather than true varieties. A number of plants were taken up, the fronds cut off and pressed, and the rhizomes planted in a window garden; at this time, Dec. 21, 1922, new fronds are appearing.

Botrychium multifidum (Gmel.) Rupr. var. **simplicius**, n. var. The plant is about 1.5 dm. high, smaller and more slender than the specific type; the sterile segment is fleshy, about 3 cm. wide; the lateral divisions are 2 cm. long and the terminal $2\frac{1}{2}$ cm., biternate with 9 segments, the terminal one of each division more or less deeply 3-lobed; general outline of sterile segment and of its divisions is much as in the specific type, the lateral divisions subequal and 6–8 mm. long; margins are sub-entire to crenate or serrate; fertile segment small, about 3 cm. long, twice pinnate, overtopping the sterile by from 1 to 4 cm. It bears the same relation to the species that the variety *tenuifolium* of the preceding species does to its variety *obliquum*. Moist, sandy borders of streams. Keweenaw Co., Farwell, No. 627 in part, July 31, 1888 and Algonac, No. 2715, June 6, 1912.

Potamogeton foliosus Raf. var. Niagarensis (Tuckerm.) Morong. Clinton River near Utica, No. 6309, Aug. 2. A form with elongated stems and leaves due to its growth in running water instead of in still waters.

Tripsacum dactyloides L. Near the railroad station at Utica, No. 6297, Aug. 2. This is the second known station for this species in Michigan.

Panicum dichotomiflorum Michx. This species during the past seven years has spread rapidly in Detroit and can now be found in every section of the city. Oxford, No. 6416, Oct. 4.

Panicum virgatum L. var. Cubense Griseb. A more slender

plant than the species with smaller spikelets which are obtuse. Near Ypsilanti, No. 6324, Aug. 9.

Chaetochloa imberbis (Poir.) Scribner. A few specimens of this species were found on a vacant lot in Detroit. Farwell, No. 6467, Oct. 28.

Reboulea pallens (Spreng.) Farwell var. major (Torr.) Farwell. In a tamarack swamp near Washington; it has more or less pubescent sheaths. No. 6194, June 21.

Eragrostis capillaris (L.) Nees. Usually said to be branching only at the base; all leaves on the culms bear in their axils short branches ending in secondary panicles. Detroit, Farwell, No. 6387, Sept. 15.

Eragrostis Eragrostis (L.) Karsten. Lansing is the only recorded station for this species in Michigan. A new station is Oxford, No. 6435, Oct. 4.

Carex riparia W. Curtis var. impressa S. H. Wright. This variety again turned up at Newport. No. 6227, July 5.

Pontederia, Linnaeus, *Sp. Pl.*, I (1753): 288 et *Gen. Pl.*, (ed. 5, 1754), No. 361. As defined by Linnaeus in the *Genera*, this genus is restricted to his *P. hastata*, the only species named by him in the *Species Plantarum* that had a many-seeded, 3-celled capsule, as was pointed out by Rafinesque about a century ago.

Narukila, Adans., *Fam. Pl.*, II (1763): 54, 581, usually referred to Pontederia is of course Phrynium Willd. and belongs to the Marantaceae.[1]

Pontederia of most American authors is Unisema Raf., *Med. Repos. New York*, V (1808): 352. In his *Medical Botany*, II (1830): 105–108, Rafinesque names and describes some ten species of Unisema, but does not use the name *cordata* for any of them. Our common species, therefore, becomes **Unisema cordata** (L.), n. comb. *Pontederia cordata* L., *l.c.* Stem leaves

[1] It is based upon the *Naru Kila*, Rheede, *Hortus Malabaricus*, 11: 67, t. 34, which is *Pontederia ovata*, Linnaeus, *Sp. Pl.* (1753), p. 288; Adanson made it coextensive with the Linnaean Pontederia, but as the name was adopted from Rheede it must go with his species which is the type of Willdenow's Phrynium. *Phrynium capitatum* Willd., *Sp. Pl.*, I (1797): 17, therefore becomes **Narukila ovata** (L.), n. comb.

oblong or oblong-lanceolate, 1–2 dm. in length and 4–8 cm. wide above the basal lobes, sagittate-cordate. The common form. Belle Isle, Farwell, No. 1294, Aug. 12, 1892. Rather frequent in shallow water along the borders of lakes and streams in southeastern Michigan. *U. media*, *obliquata*, *acutifolia* and *mucronata* Raf., *l.c.*, probably belong here. A form with much smaller and narrower lanceolate leaves, 10–15 cm. long and 2 or 3 cm. wide near the base, not cordate but usually cuneately narrowed to the petiole, is forma **angustifolia** (Pursh), n. comb. *P. angustifolia* Pursh, *Fl. Am. Sept.*, I (1814): 224. *U. deltifolia*, *Purshiana*, and *heterophylla* Raf., *l.c.*, probably belong here. Borders of a small lake near Shelbyville, Farwell, No. 5951½, July 31, 1921.[2]

Phrynium, Loefl. *Iter Hisp.* (1758), p. 178. This is the oldest name for the genus often known as Shollera or Heteranthera. Our common form in streams and ponds, often a meter in length with thin, translucent, linear leaves often a dm. long, is **Phrynium dubium** (Jacq.), n. comb.; *Heteranthera dubia* (Jacq.) MacM., *Met. Minn.* (1892), p. 138. Lake Orion, Farwell, No. 903, Aug. 29, 1895. Often growing on muddy banks and rooting at the joints, forming dense mats of shortened stems and leaves, the latter quite fleshy, not at all translucent, 3 or 4 cm. long and 2 or 3 mm. wide. This creeping form of muddy banks may be known as **Phrynium dubium** var. **terrestre,** n. var. Shores of the Clinton River near Utica, No. 6311, Aug. 2.

Allium Cepa L. var. bulbellifera Bailey. A small colony of this variety of the onion was found in a flourishing condition along the grassy banks of the Wabash Railroad near Romulus. No. 6171, June 7.

Betula Alleghanensis Britt. Very similar in general appearance to that of *B. lutea*, but the cones are only half as large and present a striking contrast when the two species grow

[2] In the herbarium of Parke, Davis & Co. are two sheets of this species with sagittate-cordate broadly ovate (18 cm. long by 13 cm. wide) to suborbicular (11 cm. long by 8.5 cm. wide) leaves which may be known as forma **latifolia** n. f. New Jersey; Franklin, Aug., 1873; Secancus, Sept. 15, 1890. Both collected by Dr. H. H. Rusby. Probably belonging here are *U. latifolia* and *U. rotundifolia* Raf., *l.c.*

side by side. St. Clair Co., near Anchorville. No. 6399½, Sept. 27; Detroit, Farwell, No. 1863, Aug. 24, 1904.

Fagus Americana Muench. The common form of the beech in Michigan. Farwell: Parkedale, No. 3256, Oct. 27, 1912; Tecoma, No. 4634, Sept. 23, 1917; near Farmington, No. 4447½, May 19, 1917; Detroit, No. 2021½, June 16, 1907; Newport, No. 6234, July 5, 1922 and Anchorville, No. 6398, Sept. 27, 1922. A form with reddish fruit is forma **Caroliniana** (Loud.), n. comb. (*F. ferruginea* var. *Caroliniana* Loud., *Arb. Frut. Brit.*, III [1838]: 1980, Fig. 1915.) Rare in Michigan where it was collected at Highland Park, No. 865, May 7, 1896. Station since destroyed.

Quercus Muhlenbergii Engelm. var. **Alexandri** (Farwell), n. comb. (*Q. acuminata* var. *Alexandri* Farwell, *Mich. Acad. Sci.*, VI [1904]: 206.) Britton described this independently and about the same time as *Q. Alexanderi*. It was found near French Landing, No. 6174, June 7, and at Newport, No. 6225, July 5.

Rumex elongatus Guss. (? *Rumex obtusifolius* × *crispus* Trelease.) At Utica there is a species of dock often with few, long, slender, leafless racemes that give it a peculiar appearance as compared with *R. crispus* or *R. obtusifolius;* the valves of the fruit are similar to those of *R. crispus*, but toothed as in *R. obtusifolius;* the leaves vary from ovate-heart-shaped and obtuse to lanceolate and acute, the base from truncate to tapering to the petiole, and the margins from strongly to scarcely wavy or crisped. It probably is the *R. obtusifolius* × *crispus* of Trelease and the *R. elongatus* Guss. of Gray's *New Manual.* It is doubtful if this is a hybrid, however, notwithstanding that it is exactly intermediate between the supposed parents, because there are many regions where the latter are found growing together in great profusion with no sign of intermediate forms that may be due to hybridization, and because it is of comparatively recent introduction and is said to be spreading rapidly. No. 6300, Aug. 2.

Polygonum lapathifolium L. A polymorphous species showing a wide variation between its extremes, but with many intermediate forms connecting them and passing one into an-

other. The typical form with vars. *incarnatum* and *salicifolium* usually have purplish flowers, but individuals may have flowers that vary to nearly white. The vars. *tomentosum* and *incanum* usually have greenish-white flowers, but some plants have the flowers strongly suffused with rose; the latter usually have the peduncles more or less glandular while the former are usually glandless or obscurely glandular; they also have slightly larger flowers ($2\frac{1}{2}$–3 mm.) and fruits which are suborbicular, while in the former the fruits are ovoid. The typical form of the species is now considered by most authors to be the form that was called *P. nodosum* by Persoon. Farwell: Detroit, No. 6386, Sept. 15, 1922 and No. 1442, Sept. 25, 1893; Oakland, No. 5122, Sept. 15, 1918; Ypsilanti, No. 5346, Aug. 31, 1919.

Var. *incarnatum* (Ell.) Wats. A large and robust variety often over 2 m. in height with elongated and drooping spikes, the leaves usually large and acuminate. Farwell: Ypsilanti, No. 5345, Aug. 31, 1919; Keweenaw Co., No. 454, Aug. 20, 1886; Detroit, No. 454a, Aug. 15, 1893; Grosse Isle, No. 454b, Aug. 14, 1909.

Var. *salicifolium* Sibth. A small variety with narrow leaves white-tomentose underneath; the upper leaves often become glabrous. Farwell: Detroit, No. $6384\frac{1}{2}$, Sept. 15, 1922 and No. 475a, Aug. 16, 1896.

Var. *incanum* (Roth) Koch. *P. incanum* F. W. Schmidt. All leaves permanently white-woolly underneath. Farwell: Keweenaw Co., No. 475, Sept. 10, 1886.

Var. *tomentosum* (Schrank) Schuster. *P. tomentosum* Schrank. *P. scabrum* Moench. Larger than the preceding variety and with only the lowermost leaves white-woolly underneath. Farwell: Oakwood, No. 5123, Sept. 15, 1918; Detroit, No. 6385, Sept. 15, 1922 and No. 474a, Sept. 15, 1897; Keweenaw Co., No. 474, Sept. 10, 1886; Oxford, No. 6376, Aug. 23; Pontiac, No. 6365, Aug. 16.

Polygonum Pennsylvanicum L. var. **viridialbum**, n. var. Similar to the variety *laevigatum*, but the flowers are greenish-white, i.e., white with a broad green stripe on the back along the mid-nerve; spike short and densely flowered, 1–3 cm. long

by 1–1½ wide, erect; fruiting perianth broadly ovoid or suborbicular, 3–4 mm. long, achene suborbicular, 2½–3½ cm., black, smooth, somewhat shining, both surfaces concave; peduncles densely glandular. Moist grounds in waste places. Detroit, Farwell, No. 6384, Sept. 15, 1922.

POLYGONUM SAGITTATUM L. *P. sagittatum* var. *Americanum* Meisn. in DC. *Prodr.*, XIV (1856): 132. The type locality as given by Linnaeus is "*in* Virginiae, Marylandiae *madidis*." The species from this region is illustrated by Plate XII of the *Hort. Cliff.* and shows the ordinary form with lanceolate leaves having sagittate bases. The leaves have bristly ciliate margins and the mid-nerves, underneath, are copiously prickly with reflexed prickles, especially on the lower half, the upper half often being naked. The flowers are rose-colored. Roadside ditches at Detroit, Farwell, No. 456a, Sept. 30, 1897 and Keweenaw Co., No. 456, Aug. 20, 1886. In an extensive cedar swamp near Oxford is a very slender form that has smaller and broader usually sagittate-oval or oblong leaves, the smaller ones often suborbicular, 1–4 cm. long by 1–1½ wide, the margins smooth and naked, the mid-nerve below with fewer and more slender prickles; flowers white; No. 6369, Aug. 23. It may be known as P. SAGITTATUM L. var. **ovalifolium,** n. var.

CYCLOLOMA ATRIPLICIFOLIUM (Spreng.) Coult. Mr. Gladewitz found this at Romulus, June 7, 1922. It is plentiful at Pontiac; No. 6362, Aug. 16. In both instances it was found along the railroad tracks.

ATRIPLEX HASTATA L. A variable species; this and the next two are usually united by American authors, but kept distinct by European. All three have innumerable varieties, forms and synonyms. It is often over a meter in height and widely branched with the deltoid-hastate leaves which often measure a decimeter each way. Usually the basal lobes spread outward and downward. In non-saline soil it is glabrous; but in saline soil it is generally smaller in every way, with the young plant densely white-scurfy; in the fruiting plants only a trace of this scurfiness remains, while the leaves are often as small as 1 cm. each way. Farwell: Detroit, No. 1411, Aug. 18, 1893 and

No. 5116, Sept. 14, 1918; Ypsilanti, No. 1411a, June 27, 1894; Oakwood, No. 4106, Sept. 23, 1915 and Nos. 5127 and 5128, Sept. 15, 1918; Almont, No. 6275, July 19.

Atriplex patula L. Leaves hastate-lanceolate with the basal lobes usually pointing outward and upward. Rare as compared with the preceding and the following. Farwell: Detroit, No. 349a, Aug. 18, 1893; Almont, No. 6278, July 19.

Atriplex littoralis L. var. marina (L.) Smith. *A. littoralis* var. *serrata* (Huds.) Moq. & var. *sulcata* (Michx.) Beck; *A. hastata* var. *littoralis* of American authors. The typical form of the species with narrowly linear, entire leaves has not been observed here. Our plant is the var. *marina* with broader, narrowly lanceolate leaves, upper ones usually entire, the lower with very small and short basal lobes or often only one and otherwise entire. Farwell: Keweenaw Co., No. 349, Sept. 4, 1885; Detroit, No. 349b, Aug. 18, 1893 and No. 6410, Sept. 27, 1922; Northville, No. 6454, Oct. 18.

Salsola Kali L. The typical form of this species with short awl-shaped leaves was found along railroad tracks at Pontiac, No. 6357, Aug. 16. The variety *Caroliniana* (Walt.) Nutt. at Oxford, Nos. 6430 and 6431, Oct. 4. The var. *tenuifolia*, Tausch. at Northville, No. 6447, Oct. 18, and at Pontiac, No. 6358, Aug. 16. The var. *tenuifolia* seems to be the commonest form as well as the largest and most bushy-branched. Variety *Caroliniana* is the lowest and simplest form, the branches often few and elongated; the calyx wings mostly red, but often this color disappears in drying. The typical form was the most compact and dense. Pontiac is the only station where it has been observed in Michigan.

Allionia Nyctaginia Michx. var. **minor** (Choisy), n. comb. *Oxybaphus glabrifolius* Vahl. var. *minor* Choisy in DC. *Prodr.*, XIII^2 (1849): 431; *O. Nyctagineus* (Michx.) Sweet var. *oblongifolius* A. Gr. in Torr., *Bot. Mex. Bound. Surv.*, (1859): 174; *A. Nyctaginea* Michx. var. *ovata* (Pursh) Morong, *Mem. Torr. Club*, V (1895): 146. A form with ovate-lanceolate leaves, obtuse or acute at base not in the least cordate. Pontiac, No. 6356, Aug. 16.

Anychia Canadensis (L.) B.S.P. A small and delicate plant that may be readily overlooked. No. 6286, July 26.

Silene antirrhina L. f. **apetela,** n. f. Differs from the typical form only in the absence of petals. Along the railroad tracks near Washington, where it was abundant. The young calyx is oblanceolate in outline, but at maturity ovoid-campanulate, 5–7 mm.; lobes always small and purplish. No. 6198, June 21.

Hepatica Americana (DC.) Ker. f. candida Fernald. *H. Hepatica* var. *albiflora* (Raf.) Farwell, as to the plants.

Hepatica Americana f. rhodantha Fernald. *H. Hepatica* var. *vulgaris* (Mill) Farwell, as to the plants.

Hepatica Americana f. **purpurea** (Farwell), n. comb. *Hepatica Hepatica* var. *purpurea* Farwell, *Mich. Acad. Sci. Rpt.*, XVII (1916): 169.

Hepatica Americana var. **parviflora** (Raf.), n. comb. *H. Hepatica* var. *parviflora* (Raf.) Farwell, *l.c.* A peculiar form of the species with the petaloid calyx as short as the involucre, or shorter; blue, and only half as large as in the type or smaller. Mrs. Cahn found a full double-flowered form of this variety at Loon Lake in Oakland Co. growing naturally in the wilds, May 1, 1922. It may be known as **H. Americana** var. **parviflora** f. **Cahnae,** n. f.

Sophia pinnata (Walt.) Howell var. brachycarpa (Richards.) Farwell. This annual plant was observed for the first time in twenty years, this time along the tracks of the Wabash Railroad at French Landing, Wayne Co. No. 6172, June 7.

Cheirinia parviflora (Nutt.) Farwell. The first time observed in over a quarter of a century and the first time seen in the Southern Peninsula. Romulus, No. 6169, June 7.

Erysimum officinale L. The plant of the typical form of this species, especially the pods, is clothed with a minute pubescence. It is rather scarce. Oxford, No. 6429, Oct. 4; Northville, No. 6464, Oct. 18; Parkedale, Farwell, No. 2949½, July 28, 1912 and Detroit, No. 2098, July 31, 1909. The most widely spread form of the species and a pernicious weed is var. **leiocarpum** (DC.), n. comb. *Sisymbrium officinale* var. *leio-*

carpum DC., *Syst.*, II (1821): 460. It differs from the species in being glabrous. Farwell: Keweenaw Co., No. 802, Aug. 21, 1890; Ypsilanti, No. 802a, May 23, 1891; Detroit, No. 802b, July 21, 1892; Marquette, No. 802c, July 6, 1895.

SINAPIS ARVENSIS L. The typical form has short, thick and glabrous pods. *Brassica arvensis* (L.) Rabenhorst. Farwell: Ypsilanti, No. 630g, Aug. 12, 1891; Detroit, No. 630h, July 16, 1892. A form with hispid pods and pedicels is var. *Orientalis* (L.) Koch et Ziz. *Sinapis Orientalis* L. Ypsilanti, No. 6335, Aug. 9. Farwell: Rochester, No. 2089, June 30, 1909. A form with much longer and more slender glabrous pods more distinctly moniliform is var. Schkuhriana (Reichb.) Hagenbach. (*Brassica arvensis* var. *Schkuhriana* (Reichb.) Thellung.) Linden, No. 6350, Aug. 16; Ypsilanti, No. 6336, Aug. 9; Farwell: Keweenaw Co., No. 630a, Aug. 1, 1890 and at Rochester, No. 4507, June 28, 1917.

ERUCASTRUM GALLICUM (Willd.) O. E. Schulz. This species looks very much like a species of Radicula, at first glance. So far as I am able to ascertain, this is the first time that it has ever been reported for North America, to which, apparently, it must be a new introduction. The plant is about 4 or 5 dm. in height and somewhat branched or simple; the flowers are pale yellow; the pedicels are horizontal to ascending, the pods extending in the same straight line with the pedicel, or more often pedicel and pod are curved in an arc; more rarely some of the pods are slightly curved backwards; the beak of the pod is very slender and without a seed. Plentiful along the railroad tracks near Ypsilanti; No. 6334, Aug. 9.

DIPLOTAXIS MURALIS (L.) DC. A new station for this plant is Pontiac; No. 6360, Aug. 16. It was at one time widely dispersed in Detroit and quite abundant; Farwell, No. 1644, July 15, 1899.

ERUCA ERUCA (L.) Asch. & Graebn. This was found to be a weed in cultivated grounds at Parkedale and on adjacent roadsides to which it had spread. Farwell, No. 3512, July 20, 1913.

RIBES LACUSTRE (Pers.) Poir. In the *Michigan Flora*, this species is said to occur as far south as Houghton Lake, which

is in Roscommon Co. It was found in a sparsely wooded pasture near Rochester, Oakland Co., July 21, 1922. It was well scattered over the pasture, but the cattle had browsed upon it and there was no sign of either flowers or developing fruit. Not a plant was found that had not been extensively cropped. Farwell, No. 6280. This station is about 150 miles southeast of Houghton Lake.

Potentilla intermedia L. This species is well established in Macomb Co. Washington, No. 6199, June 21.

Geum Canadense Jacq. Fernald and Weatherby have[3] recently revised this species, recognizing besides the type, 3 varieties and 2 forms. Supposed to be growing in Michigan are the type and its forma *glandulosum;* var. *camporum* and its forma *adenophyllum.* The summer's collection revealed *G. Canadense* forma *glandulosum* Fern. & Weath. Newport, No. 6242, July 5; Northville, No. 6460, Oct. 18. Also var. *camporum* (Rydb.) Fern. & Weath. Almont, No. 6275½, July 19.

Geum flavum (Porter) Bicknell. Another station for this species was found at Hamburg. It is similar to the preceding species, but the petals are of a cream color and shorter than the calyx lobes. No. 6257, July 12.

Rosa blanda Ait. Collected at Ypsilanti, which is rather far south for this species. No. 6219, June 28.

Rosa Woodsii Lindl. This species was frequent on the railroad banks near Romeo. The first time I have seen it in over thirty years or since leaving the Keweenaw Peninsula. No. 6191, June 21. Mr. Gladewitz collected *R. pratincola* Greene near this location at this time.

Rosa villosa L. This species seems to be fully at home amongst the shrubbery of roadsides near Hamburg. No. 6261, July 12. At this time the species was not in flower and the fruit, though apparently fully grown, was still green and showed nothing of its typically scarlet color.

Sorbus Aucuparia L. This species was found along the roadside at Hamburg where it evidently was an escape. No. 6254, July 12.

[3] *Rhodora,* XXIV (1922): 47–50.

CRATAEGUS MONOGYNA Jacq. This species was abundant along roadsides and in fields in the southwest corner of Lapeer Co. All stages were seen, from the seedling to mature and fruiting trees. It was past the flowering stage. No. 6180, June 14.

TRIFOLIUM ARVENSE L. Roadsides at Hamburg. Scarce. No. 6255, July 12.

PHACA NEGLECTA, T. & G. forma **Limonia,** n. f. Living flowers of a bright lemon-yellow, the withered flowers white; yellow flowers fading in the press to a cream color. Southwest corner of Lapeer Co., No. 6179, June 14. As all authors emphasize the fact that the typical form of the species has a pure white flower, this color variation seems to be worthy of a name as a matter of convenience and so should be put on record.

MEIBOMIA ILLINOENSIS (A. Gr.) O. K. Only three stations are given for this species in the *Michigan Flora*. It was found to be quite wide-spread and rather common throughout the southeast section of the State. Specimens were collected as follows: Hamburg, No. 6262, July 12; Ypsilanti, No. 6347, Aug. 9; Rochester, Farwell, No. 6279, July 21, 1922.

VICIA GRACILIS Lois. Railroad banks at Ypsilanti, No. 6344, Aug. 9.

FALCATA COMOSA (L.) O. K. There are at least two strains of this species with regard to pubescence that are worth recognition. In the *Species Plantarum* of 1753, page 754, Linnaeus described *Glycine comosa* and *G. bracteata*, which are now considered to be synonymous and the same as his *G. monoica* of the second edition of the *Sp. Pl.*, 1763, page 1023, which is a substitution for *G. bracteata*. *G. comosa* is described as with leaves "hirsutus," and *G. bracteata* as with leaves "nudiusculus" and with stems that are "*retrorsum griseo-pilosus*." One of our forms has the stems glabrate to retrorsely pubescent *with grayish hairs mostly appressed or very nearly so* and the leaflets are glabrous or essentially so; this form corresponds to the Linnaean *G. bracteata*. The second form has the leaves more pubescent and the stem is pilose with *brown* hairs which are *not in any wise appressed, but horizontally or retrorsely spreading*.

It may represent the form called *G. comosa* by Linnaeus and I will so accept it and take it to be the type form of *Falcata comosa* (L.) O. K. Newport, No. 6246, July 5; Detroit, Farwell, No. 1317, Aug. 26, 1892. The other form becomes **Falcata bracteata** (L.), n. comb. Pittsfield, No. 6211½, June 28; Newport, No. 6238, July 5; Royal Oak, Farwell, No. 5592, Aug. 12, 1920.

Falcata Pitcheri (T. & G.) O. K. This differs from *F. comosa* in having the pubescence coarser and denser, but of the same brown color, the leaves larger and thicker, and the raceme usually branched. Grosse Isle, Farwell, No. 2181½, Aug. 11, 1910. Evidently all the forms intergrade and they are probably but different phases of one species.

Ilex verticillata (L.) A. Gr. So far as my experience goes, the commonest form of this species in southeastern Michigan is the var. *tenuifolia*. The year 1922 was most favorable for observations as the fruit was abundant and made the species a very prominent feature of the landscape. The typical form was easily recognizable by its small, bright red fruit 4–8 mm. in diameter with seeds 3¾ mm. long. The variety had larger, darker red fruit 7–11 mm. in diameter with seeds 4¼ mm. long. The leaves were much alike as to size, shape and pubescence, but those of the variety were minutely puncticulate under a lens while those of the species were not. The branchlets of the species were brown, while those of the variety were gray; or brown on one side and gray on the other. In the species the fruits are more apt to be two or three together while in the variety they are more apt to be single. However, the two forms intergrade and pass one into the other, and the only constant character on which the two forms may be separated is that of the pellucid dots in the leaves of the variety. The species is represented by the following numbers: Pittsfield, No. 6213, June 28; Utica, No. 6318, Aug. 2; Northville, No. 6453, Oct. 18.

Var. *tenuifolia* (Torr.) Wats. Represented by the following collections: Lapeer Co., No. 6181, June 14; Lakeville, No. 6445a, Oct. 11; Northville, No. 6449, Oct. 18; Anchorville,

No. 6472, Nov. 5. No. 6181 was collected from plants growing along roadsides on the top of a hill in dry, more or less stony ground, a very unusual habitat.

Var. *cyclophylla* Robinson. A form with suborbicular leaves, 2 to 4 cm. along the mid-rib and obtuse at the base, probably should be placed here. Detroit, Farwell, No. 6446, Oct. 15, 1922.

Aesculus glabra Willd. Gibralter, No. 6153, May 31.

Vitis cordifolia Michx. Newport, No. 6243, July 5.

Althaea officinalis L. Near La Salle this species has spread extensively into low marshy grounds. No. 6291, July 26,

Lechea Leggettii Britt. & Holl. In an open woods at La Salle; No. 6281, July 26.

Aralia hispida Vent. This species is known as dwarf elder and was found near Romulus where there was a good-sized colony of it. This station is rather far south for it. No. 6166, June 7.

Fraxinus Americana L. f. iodocarpa Fernald. This form differs from the type in having the fruit deeply tinged with purple. Southwestern corner of Lapeer Co., No. 6185 and near by in Oakland Co. No. 6186, June 14.

Fraxinus Biltmoreana Beadl. Looks considerably like a pubescent form of *F. Americana*, or intermediate between that and *F. Pennsylvanica*, for which it was originally collected. Belle Isle, No. 84b, June 24, 1893 and at Junior, No. 4807a, Oct. 28, 1917.

Fraxinus lanceolata Borck. Said to be scarce in Michigan. Keweenaw Co., No. 84, May 15, 1884; Parkedale, No: 3247, Oct. 27, 1912. Southeast corner of Genesee Co., No. 6177, June 14.

Fraxinus quadrangulata Michx. This species is about as rare in Michigan as the preceding. Keweenaw Co., No. 726, Sept. 10, 1889; Belle Isle, No. 2213½, June 16, 1911; Near Farmington. Billington and Farwell, No. 5091, July 14, 1918.

Three other species, *F. Americana* L., *F. nigra* Marshall and *F. Pennsylvanica* Marshall, are more or less common throughout the State.

Asclepias purpurascens L. One of the rare milkweeds in Michigan. During thirty years of field work in southeastern Michigan I have seen it on only 3 or 4 occasions, and there were not more than three or four plants at any of the localities where it was seen. Ypsilanti, No. 6214, June 28; La Salle, No. 6284, July 26.

Asclepias Sullivantii Engelm. In fields near the railroad tracks near La Salle, where it was found in goodly numbers. No. 6288, July 26.

Convolvulus arvensis L. Typical form was collected at Detroit No. 1470, July 10, 1894 and at Marquette, No. 1470a, July 6, 1895. It had ovate or oblong leaves with the basal lobes sharply acute.

Var. *obtusifolius* Choisy. Differs in having the basal lobes obtuse instead of acute. The leaves are variable, often 6 cm. long and two thirds as wide to 3 cm. and one sixth as wide. Waste places at Utica, No. 6299, Aug. 2.

Var. *parvifolius* Choisy. Basal lobes acute as in the typical form of the species, but the leaves are reduced in size being one or two cm. in length, and, exclusive of the basal lobes, essentially suborbicular. Washington, No. 6200, June 21.

Echium vulgare L. Ypsilanti township, west of the city of the same name, No. 6222, June 28.

Verbena Urticifolia L. var. **simplex,** n. var. Stems 4 to 8 dm. in height, strictly simple and terminated by a single filiform raceme about a decimeter in length and often with a similar simple raceme from the axiles of the 3 or 4 uppermost pairs of leaves. Nutlets smaller than those of the typical form, $1\frac{1}{4}$–$1\frac{1}{2}$ mm. in length. A slender, unbranched woods form with smaller flowers and fruits. In woods near Lakeville, Billington, Farwell and Gladewitz, No. 6443, Oct. 11, 1922; Northville, No. 6463, Oct. 18. Mr. Gladewitz has collected it also near Vassar.

Monarda mollis L. f. **albiflora,** n. f. Differs from the species in its pure white flowers. Almont, July 19; La Salle, No. 6292, July 26. I collected this many years ago at Royal Oak in company with the late Mr. Brotherton, No. $2127\frac{1}{2}$, Aug. 24, 1909.

Clinopodium acinos (L.) O. K. This small mint, often called mother-of-thyme, is a new denizen of Michigan. It is a native of Europe, but has become naturalized in the region from Ontario to Mass. Oxford, No. 6375, Aug. 23.

Koellia Virginica (L.) Farwell. This narrow-leaved species was found at a new station. As usual for this species it was scarce. Utica, No. 6296, Aug. 2.

Koellia pilosa (Nutt.) Britt. On Sept. 21, 1921, we found at La Salle a species of Koellia overripe and uncharacteristic with short ovate leaves, which was taken to be a variety of *K. Virginiana*. A visit to the place in the following July proved it to be *K. pilosa*, a species that had not before been recorded for this State. It was found in abundance. The plant looks very much like a densely pubescent, broad-leaved form of *K. Virginiana*, but is much taller than that species and grows in drier situations. No. 6023, Sept. 21, 1921 and July 26, 1922.

Lycopus Virginicus L. This species was collected in a low swampy woods at Northville. It differs from *L. uniflorus* in its non-tuberous base and in its more slender, filiform stolons, which do not bear tubers. No. 6461, Oct. 18. Rare in Michigan.

Mentha rotundifolia (L.) Huds. A rare species of mint in Michigan. It has a strong spearmint-like odor. Detroit, No. 2222, July 22, 1911; Leesville, No. 6411, Sept. 27, 1922.

Mentha crispa L. Roadsides near La Salle, No. 6287, July 26. Evidently an escape from cultivation near by.

Mentha gentilis L. Banks of the Clinton River near Utica. No. 6306, Aug. 2.

Mentha arvensis L. Typical form of the species with ovate leaves having a rounded base and the lowermost small and orbicular or nearly so. Swamps near Washington, No. 6196, June 21. Young plants 4 or 5 dm. in height, but too early in the season for flowering specimens.

Veronica Anagallis-aquatica L. var. glandulosa Farwell. Another locality of the glandular form was discovered. It seems to be the prevailing form in southeastern Michigan. Washington, No. 6201, June 21.

Galium circaezans Michx. var. glabrum Britt. A smooth-

ish form of the species in which the pubescence is confined essentially to the margins of the leaves. Hamburg, No. 6266, July 12.

GALIUM CONCINNUM T. & G. Said to be rare in Michigan. Widely distributed, but scarce in any one place. Ypsilanti, No. 6224, June 28; Geddes, No. 2123, Aug. 21, 1909; Zoölogical Park near Royal Oak, No. 4414, Aug. 27, 1916.

GALIUM CLAYTONI Michx. One of our rarest bedstraws; widely dispersed, but scarce in any one place. Hamburg, No. 6249, July 12; Keweenaw Co., No. 758, July 18, 1890; Detroit, No. 758a, July 21, 1892; Parkedale, No. 2651, June 9, 1912.

DIODIA TERES Walt. Another locality was discovered for the species, making the second known to us. Pontiac, No. 6366, Aug. 16.

CAMPANULA ROTUNDIFOLIA L. The typical form, with linear to linear-lanceolate stem leaves and with the base of the stems densely puberulent, is scarce. Keweenaw Co., No. 306, Aug. 6, 1885; Ypsilanti, No. 306a, June 13, 1891; Marquette, No. 306b, July 6, 1895; Detroit, No. 306c, July 8, 1908. The commonest form of the species in Michigan differs only in having the base of the stem glabrous or with but slight pubescence, and that in lines. It may be known as:

CAMPANULA ROTUNDIFOLIA L. var. **intercedens** (Witasek), n. comb. (*C. intercedens* Witasek). Hamburg, No. 6256, July 12. Parkedale, No. 2756, June 30, 1912 and No. 2845, July 14, 1912. A form of this variety with very narrow leaves may be known as:

Campanula rotundifolia var. **intercedens** forma **linifolia,** n. f. It does not differ from the variety except in the very narrowly linear leaves $\frac{1}{4}$ to $\frac{3}{4}$ mm. in width. Moist, sandy ditches along roads at Hamburg, No. 6263a, July 12. Another form of the variety *intercedens* when growing in the crevices of cracks in sunny situations becomes dwarfed and more rigid with fewer flowers, or often only one flower. It may be known as:

Campanula rotundifolia var. **intercedens** forma **dubia** (A. DC.), n. comb. (*Campanula dubia* A. DC.) Keweenaw Co., No. 340, Sept. 1, 1885; Marquette, No. 340a, July 6, 1895.

LACINIARIA SPICATA (L.) O. K. f. **albiflora** (Britt.), n. comb.

Flowers white; whole plant very resinous. Collected on Harsens Island by Mr. Gladewitz where he said it is quite frequent.[4]

SOLIDAGO ARGUTA Ait. This goldenrod is not listed in the *Michigan Flora*, nor in forty years of field work have I observed it until now. Rich woods near Oxford, No. 6419, Oct. 4. The large flower heads 5–7 mm. high, the coarsely serrate leaves and the broad lower leaves, as well as the habitat, distinguish it from *S. juncea*.

ASTER MACROPHYLLUS L. Widely dispersed throughout the State and found in many forms. Additional stations are Marl Lake, No. 4711a, Oct. 11, 1917; Lakeville, No. 6438, Oct. 11.

Var. *velutinus* Burgess. No. 3085, Aug. 24, 1912.

ASTER SCHREBERI Nees. Rochester, No. 3854, Sept. 17, 1914.

ASTER PANICULATUS Lam. var. CINERASCENS Fernald. The stems are strongly greyish rough puberulent. Linden, No. 6348, Aug. 16.

IVA XANTHIIFOLIA (Fresn.) Nutt. Roadsides in Keweenaw Co.; No. 619, July 26, 1888. Pontiac, No. 6363, Aug. 16.

HELIANTHUS LENTICULARIS Dougl. This species was found at Almont in waste grounds. No. 6276, July 19. Also River Rouge, No. 4338, July 21, 1916 and at Ypsilanti, No. 1191½, Aug. 5, 1891.

HELIANTHUS PETIOLARIS Nutt. Along the railroad tracks at Pontiac, where it was plentiful. No. 6364, Aug. 6.

HELIANTHUS OCCIDENTALIS Riddell. Along the railroad tracks both east and west of Ypsilanti. East of Ypsilanti, No. 1192, Aug. 5, 1891; Rochester, No. 1192a, Aug. 25, 1909. Between Ypsilanti and Ann Arbor, No. 6328, Aug. 9.

Var. *Illinoensis* (Gleason) Gates. Loosely white-woolly. Hamburg, No. 6253, July 12.

HELIANTHUS MAXIMILIANI Schrad. Dry hillsides in Keweenaw Co., No. 1653a, August, 1901; waste places in Detroit, No. 1653, Aug. 22, 1899; the preceding numbers represent plants that were about a meter in height and but slightly and

[4] This white-flowered form was collected July 31, 1922, by Mrs. F. W. Robinson of Detroit, near Ojibway, Ontario.

simply branched. At La Salle were found plants that were 2 to 3 meters in height and copiously and paniculately branched. It is a gigantic form of the species and may be known as var. **paniculata,** n. var. No. 6290, July 26. The other and reduced extreme, var. *Dalyi* (Britt.) Farwell, was found on a dry railroad bank at Oxford, No. 6425, Oct. 4.

Achillea Ptarmica L. Sneezwoort. Rare in Michigan. Waste grounds in Detroit, No. 3554, Oct. 15, 1913.

Achillea borealis Bongard. Frequent on the Keweenaw Peninsula. Copper Harbor, No. 4004, July 8, 1915 and No. 5968, Aug. 16, 1921. Heads rather large and the involucral scales black-margined.

Achillea asplenifolia Vent. *A. rosea* Desf.; *A. Millefolium* var. *rosea* T. & G.; *A. Millefolium* var. *asplenifolia* Farwell. Rays rose-pink to magenta. Ypsilanti, No. 1162, June 27, 1891; Ortonville, No. 6189, June 14.

Achillea Millefolium L. The common yarrow. Mostly green and glabrate with large and openly dissected leaves. Involucral scales green with a brown margin. Detroit, No. 431b, July 23, 1892; Rochester, No. 4584½, Sept. 12, 1917.

Achillea lanulosa Nutt. Somewhat similar to the above but densely woolly in all its parts, leaves smaller with divisions close and more prickly, corymb very convex. Keweenaw Co., No. 431, July 26, 1886; Ypsilanti, No. 431a, June 21, 1891; Detroit, No. 431c, Aug. 4, 1899; Parkedale, No. 2762, June 30, 1912; Washington, Nos. 6005 and 6006, Sept. 14, 1921; Woodville, No. 5459, Aug. 4, 1921; Royal Oak, No. 5787½, Aug. 19, 1920. A form of this has the rays colored "laelia pink," according to Ridgeway's standard colors, and may be known as forma **rubicunda,** forma nov. Roadsides and fields at Washington, No. 6193, June 21.

Achillea occidentalis Raf. This differs from the above in its smaller cylindrical heads with involucral bracts all stramineous and without a dark-colored border. Washington, No. 6192, June 21. Slocum's Island, No. 5985, Aug. 31, 1921; Marl-Lake, No. 5710, Sept. 18, 1920.

Tussilago Farfara L. Coltsfoot. A small patch of colts-

foot was found in a tamarack swamp at Washington. It seemed to be as native as any of the other botanical denizens and if an introduction and naturalized it is the only such species to be found there. At the time we were there, there was no evidence of either flowers or fruit, No. 6195, June 21.

Erechtites hieracifolia (L.) Raf. var. intermedia Fernald. In this variety the upper leaves are reduced and bract-like. Oxford, No. 6371, Aug. 23.

Carduus acanthoides L. This species of plume thistle is rare in the New World, being found only on ballast grounds from Nova Scotia to New Jersey. It is found on the farm of Mr. J. C. Townsend, in Addison Township, Oakland County, where it has been a denizen for at least twelve years. A very handsome plant when in full bloom. Billington, Farwell and Gladewitz, No. 6436, Oct. 11, 1922.

Cichoryum Intybus L. Chicory. A widely dispersed weed. It has three color variations, the commonest being blue generally considered to be the typical form. Detroit, No. 1327, Sept. 23, 1892; Copper Harbor, No. 1327a, Aug. 23, 1898. A pink or pale rose-colored flower is frequent and may be known as f. **rubicunda,** n. f. Collected some years ago at Detroit. A third form has pure white flowers and may be known as f. **alba,** n. f. Collected some years ago at Detroit. Also at New Baltimore, No. 6390, Sept. 27, and Anchorville, No. 6391, Sept. 27.

Var. *divaricata* DC. Heads on spreading peduncles. Detroit, No. 1650, Aug. 4, 1899.

Virea autumnalis (L.) S. F. Gr. This is commonly called the fall dandelion. In 1904 two localities only were recorded in the *Michigan Flora*. It is quite plentiful on a lawn at Almont, No. 6277, July 19. This is listed in Gray's *Manual* under Leontodon, but as the common dandelion is the type species of that genus and as the two are not con-generic, this must take another name. Britton and Brown use the generic name Apargia of Scopoli, 1772, but Virea Adanson has nine years priority.

Lactuca Canadensis L. var. longifolia (Michx.) Farwell f. **angustipes** (Wieg.), n. comb. *Lactuca Canadensis* L. var. *typica*

f. *angustipes* Wieg., *Rhodora*, XXII (1920): 10. Similar to the variety, but having the leaves narrowed at base instead of sagittate. Utica, No. 6312, Aug. 22. The first time I have observed any form of the wild lettuce without sagittate leaves; evidently not frequent in Michigan. The var. *latifolia* O. K. with white flowers was collected at Almont, No. 6274, July 19; this form with white flowers may be known as forma **pallida,** n. f.

Sonchus arvensis L. var. maritimus Wahl., *Fl. Suec.* (1824), p. 483; var. *glabrescens* Gunth., Grab. & Wimm., *Enum. Stirp. Phan. Siles.*, (1824), p. 127, according to S. F. Blake in Long, *Torreya*, XXII (1923): 92; var. *laevipes* Koch, *Syn.*, II (1844): 498; var. *eglandulosus*, Farwell, *Rept. Mich. Acad. Sci.*, XX (1918): 192; *S. maritimus* L., *Am. Acad.*, VIII (1789): 102, 103, *non Syst.; S. uliginosus* Bieb., *Fl. Taur. Cauc.*, II (1808): 238. This variety differs from the species in having glabrous peduncles and involucres and in being more or less glaucescent. At Detroit it is at home in an unimproved, grassy lot where it has maintained itself for many years. It has not spread by seed in this lot at least. No. 5143, Sept. 15, 1918. It was collected in Oakland Co., in what is now called the Zoölogical Park, situated between Detroit and Royal Oak, No. 4559½, Sept. 8, 1917. This, like the preceding collection, was in grass land. I have not seen it either on the ordinary waste grounds or in cultivated fields.

Hieracium Pilosella L. This small scapose hawkweed was collected during the current year in Bloomfield Township, Oakland Co., by Mr. C. Billington of Detroit. In 1904 Beal gave but one station for this species, — Benzonia.

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ATTEMPTS AT REVERSAL OF GEOTROPIC RESPONSE

A. ANNA HAIRE

INTRODUCTION

PUBLISHED papers by Small (1), Small and Rea (2), Small and Lynn (3), and Miss Lynn (4) record results which they interpret as reversals of geotropic response.

The appearance of the roots in Small's plates raised doubt as to the correct interpretation of the physiological behavior of the seedlings used The bends do not look like geotropic curvatures, but the plants look shriveled and contorted as though they might have been injured in the experiments.

Small's purpose in undertaking the experiments was to furnish evidence for his hydrion differentiation theory. Accordingly stems, supposedly inherently alkaline, were surrounded by an acid atmosphere; and roots, acid in nature as postulated, were subjected to an alkaline atmosphere, namely, ammonia vapor.

The papers by Small and Rea and Lynn already referred to, and an additional paper by Small on reversed heliotropism (5) constitute the literature on the reversals of response in organisms that are not motile. S .O. Mast (6, 7) has written of the reversion in orientation to light, and of the effects of chemicals on reversion in orientation to light of colonial forms, but reversed geotropism is not treated by him.

A series of experiments, begun in October, 1922, and continued through March, 1923, comprise the attempts at reversals of geotropic response treated in the present paper. This work was done in the Botanical Laboratory of the University of Michigan under the direction of Professor F. C. Newcombe.

EXPERIMENTS AND DISCUSSION

Only geotropic experiments with young seedlings are included here. The series of experiments consisted of four distinct groups, three with stems and one with roots. One series of stems was subjected to an acid atmosphere; the stems of another series were coated with vaseline and olive oil; and those of the third were given a carbon dioxide atmosphere; roots were kept in ammonia vapor. These were the conditions used by Small and Lynn.

The general method of supporting the seedlings in the damp chambers consisted in securing the row of seedlings between two strips of blotting paper laid upon a wooden bar; each seedling was held in place by rubber bands surrounding the wooden bar and the strips of blotting paper. The wooden bar was held in place in the damp chamber by wedging it against the sides of the jar by a short section of rubber tubing. The objectionable method used by Small of pinning through the cotyledons or the endosperm for support was never employed in this work.

Stems in Acetic Acid Atmosphere

Acetic acid atmosphere for stems should cause positive geotropism, according to Small's theory and according to his results. Acetic acid of one, five, ten and twenty per cent was used to give atmospheres of increasingly greater acidity in the experiments attempting to produce positive curvature of stems. Very short stems were used, mostly one to four centimeters long. *Pisum sativum* L. was used in only three experiments; the other experiments were all with *Zea mays* L. seedlings, the species Small found most satisfactory.

In one per cent acetic acid vapor. — One per cent acetic acid was used for the acetic acid experiments with stems because Small recorded reversed curvatures in vapor from this strength. *Zea mays* seedlings grown in sphagnum moss were fastened on supports in four-sided jars of 1300 c.c. capacity, lined with wet absorbent paper. Others were left in soil in the small crystalliz-

ing dishes in which they started, and these dishes were fastened securely in the jars. Ten cubic centimeters of one per cent acetic acid were poured into the jars, and the jars were placed in the dark from five to twelve hours with the seedlings upright. The seedlings were turned to a horizontal position by turning the jars. The atmosphere did not test acid with litmus paper at the end of twenty-four hours when it was supposed the seedlings had been given plenty of time to show growth curves. There was no evidence of reversed curvature here in the vapor from one per cent acid; there were only normal negative responses.

In five per cent acetic acid vapor. — As one per cent acetic acid vapor failed to produce positive geotropism of stems, five per cent was tried. Five cubic centimeters were put into the jars at first, and the atmosphere was kept acid by adding two cubic centimeters of five per cent acid every twelve to fifteen hours. The atmosphere was tested for acidity by suspending a piece of moistened litmus paper, blue when put in but soon changing to red.

Ten experiments with *Zea mays*, including eighty-one seedlings with stems one to five centimeters long, showed growth and bending that were only slightly less than normal, but all the curves were negative. The three experiments with *Pisum sativum* showed like results.

In ten per cent acetic acid vapor. — No reversals of curvature were obtained in five per cent acetic acid vapor, and so ten per cent was used. Seedlings on supports in vapor from this strength were injured. The roots of *Zea mays* seedlings were browned as were also the coleoptiles. The growth in this atmosphere was less than in five per cent as were also the angles of bending, but the curvatures were negatively geotropic. The seedlings in the crystallizing dishes were hardier. They showed no injury in the atmosphere from ten per cent acid; consequently, the growth was better in these stems than in those on the supports, and the angles of curvature were greater, but here also the bends were negatively geotropic.

In vapor from twenty per cent acetic acid. — As the curvatures

were still negative in the vapor from ten per cent acetic acid, twenty per cent was used, to see if curvatures would take place before the stems were injured. Ten cubic centimeters of twenty per cent acetic acid were put into a jar of 1300 c.c. capacity. No more acid was added during the course of the experiment. In atmosphere of this strength there was no growth; the stems became brown and contorted; there was no geotropic response.

Young Stems Coated with Vaseline and Olive Oil

Another way to make stems acid, Small thought, was to coat them with vaseline, causing an accumulation of the carbon dioxide of respiration. The method used in this work was very similar to that of Small and Rea. After the stems had been coated with vaseline, they were placed vertically in the dark for two or three days, and then turned to a horizontal position. *Lupinus albus* L., *Zea mays* L., *Pisum sativum* L., and *Helianthus annuus* L. were used principally; others used to a less extent were *Avena sativa* L., *Cucurbita maxima* Duchesne, and *Vicia Faba* L.

The etiolated seedlings used were grown in pots of sphagnum moss. The green seedlings used were left in the crystallizing dishes in which they were started. The stems were from seven to thirty millimeters long when first coated, and the coating was renewed often enough to insure continuous envelopment of the growing region in vaseline.

Some of these stems remained horizontal, but most of them showed upward bending with a lesser angle of curvature than normal in nearly every case. *Pisum sativum* and very young *Vicia Faba* stems were the ones that remained horizontal or drooped. These showed no growth. Penetration by the vaseline had made them translucent. The envelope of plumule leaves of *Zea mays* had protected their inner growing tissue; hence their greater growth as compared with *Pisum sativum* and *Vicia Faba*. *Lupinus albus* stems showed the best growth and the sharpest *upward* curvatures. There were no reversals of geotropic response. Some seedlings showed erratic bends, varying individually, but these behaviors were due either to the weight of

the seedlings, or, as in *Pisum sativum* and *Vicia Faba*, to the injury by the vaseline.

The seedlings which had been grown in the crystallizing dishes and had short, green stems when put into the dark room, became etiolated and tall within three days and sagged when turned to the horizontal position.

For the experiments with vaseline, eighty *Zea mays*, fifty-six *Lupinus albus*, thirty-two *Pisum sativum*, one hundred *Helianthus annuus*, fifteen *Cucurbita maxima*, thirty-seven *Avena sativa*, and fourteen *Vicia Faba* seedlings were used. These varied in length from stems of one centimeter or less on the supports, to stems four to six centimeters long in the crystallizing dishes. Specific data on all of these were kept through a period of four months with general results as described above. In all cases, the longer the stems when coated, the more likely were they to remain horizontal or sag; the younger ones except *Pisum sativum* and *Vicia Faba* showed nearly normal angles of curvature. The longer bends or saggings of the longer stems were not appreciably different from those in the controls.

The results recorded above make it certain that the vaseline method is very unsuitable. When there was much penetration by the vaseline, there were no growth and no bending; when there was little or no penetration, the curvatures were almost normal.

As vaseline was found to be very injurious to the seedling stems, olive oil was tried instead. Two experiments with *Zea mays* and two with *Lupinus albus* proved sufficient for this test. The method used was the same as with vaseline. Stems of *Zea mays* ten to twenty-two millimeters long and of *Lupinus albus* fifteen to twenty millimeters long remained horizontal in the first trial, having failed to grow; in the second trial, growth of two to three millimeters made possible slight *upward* curvatures.

Stems in Carbon Dioxide Atmosphere

As coating with oil proved unsuited for the purpose of obtaining active stems with possibly acid sap, Miss Lynn's method of using a carbon dioxide atmosphere was tried. *Helianthus annuus* was the species used principally in these experiments.

Carbon dioxide was generated and made to displace different amounts of water in graduated bell-jars. In the jars crystallizing dishes containing seedlings of various lengths were placed on standards above the water. Though the bell-jars were calibrated, only an approximate measure of the carbon dioxide was possible, and so a method of testing by titration was used in most of the experiments. A known amount of barium hydroxide was made to absorb a definite number of cubic centimeters of the gas in the bell-jar. This was titrated with hydrochloric acid of the same normality. Calculations by the use of tables of chemical data gave the true percentage.

The bell-jars containing seedlings were placed in the dark room or covered with black paper. The atmospheres, tested immediately after the experiments were set up, and again after sixteen hours or two days, showed an increase of about four per cent during the course of the experiment.

The longer stems sagged, but the upper part of the hypocotyl contained an upward bend of a small angle. The younger, shorter stems curved upward in sharp angles near the soil. The younger the seedlings, the sharper were the bends. A few longer *Lupinus albus* stems in twelve and one-fourth per cent and in twenty per cent carbon dioxide showed similar behavior. The growth region in these made an upward angle; the hypocotyl sagged. *Phaseolus vulgaris* L. in eighteen per cent carbon dioxide showed slight upward curvature in the epicotyl; the hypocotyl remained horizontal as it was no longer growing. *Cucurbita maxima* in thirty-three per cent carbon dioxide showed slight upward curvature.

Seven experiments with *Helianthus annuus*, exhibiting the same reactions as described above, included one hundred and twenty-five seedlings. In these seven experiments seedlings in crystallizing dishes were placed horizontally under bell-jars. Thirty, twenty, thirty, twelve, nine, thirteen, and eleven seedlings were subjected to carbon dioxide atmospheres of four, nine, ten, fourteen, sixteen, eighteen, and twenty per cent respectively.

Three experiments with *Lupinus albus* stems included six-

teen seedlings: eight, two, and six in percentages of carbon dioxide that were twenty, fifty, and twelve respectively. The angle of negative curvature was less and the extent of the bending region greater than in the controls, but there were no reversed curvatures.

Zea mays shoots five to eight centimeters long remained horizontal in the ten per cent and thirty-five per cent carbon dioxide. The growth even in the controls here was very little; the upward bends were extended over a long region and were of small angles.

Thirteen *Pisum sativum* stems one to four centimeters long in twelve per cent and twenty per cent carbon dioxide showed good growth and sharp upward curves with the bends at the first node.

Four *Brassica alba* Boess shoots in seventy-five per cent carbon dioxide drooped. One of these had hung limp before the carbon dioxide had displaced all of the water in the jar.

Four *Avena sativa* shoots in twenty-five per cent carbon dioxide showed upward curvature of slightly less than normal angle.

Five stems of *Fagopyrum esculentum* Moench one to four centimeters long in nine per cent carbon dioxide grew well. The shorter stems curved upward and the longer ones sagged. Miss Lynn found nine per cent carbon dioxide the critical strength, obtaining both normal and reversed curvatures in this and in higher percentages.

Of the hundreds of seedlings used in the present work only a few remained horizontal, and even a smaller number exhibited curves which had a reversed direction, but which were not growth curves. All of the other curvatures were negatively geotropic responses, normal except that the angle of curvature was less than that in the controls.

Miss Lynn's Helianthus curves look very much like the sags of the stems in the accompanying plates. Both short stems with normal upward curves and longer sagging stems are shown in Plate XVI, Fig. 2. These stems had been in fourteen per cent carbon dioxide. They had grown two centimeters in forty-

eight hours. The stems with negative curves were four centimeters long when set up; the sagging stems had measured six centimeters. Twelve stems, nine to twelve centimeters long, in twenty per cent carbon dioxide showed no growth, and therefore no curvature, but only sagging. The controls showed long gradual bends (See Plate XVII, Fig. 2).

A separate set of controls to the experiments with vaseline and carbon dioxide were run to test further for the behavior in normal atmosphere but without light. Seedlings of various species were grown in crystallizing dishes, and when the stems were just emerging from the soil, were set in the dark room in a horizontal position and left for a week. This test was made because Miss Lynn states that untreated stems in the dark sometimes become acid enough to make downward curves. Observations were made each day. The results stated briefly are as follows:

Sixteen *Avena sativa* shoots showed upward curvature at first, but upon becoming longer sagged.

Three *Lupinus albus* stems showed lengthening of the region of curvature.

Sixteen *Zea mays* shoots varied in their behavior, some curving upward, some sagging, and some remaining horizontal.

Five *Pisum sativum* stems showed sagging, with the bend two centimeters from the soil, but in the growing regions there were upward curves.

Five *Cucurbita maxima* stems showed sagging with upward curvatures in the growing region.

Seven *Phaseolus vulgaris* stems included upward bending just below the cotyledons, saggings, no bending, and turning in a horizontal plane, but bending up at the end.

In no case after a week's time were there sharp upward curvatures in the stems of these control seedlings. The regions of curvature were lengthened and the angles were reduced after the first two or three days, because of the progress of the region of growth. Almost the same characteristics were shown in these control seedlings as in the stems coated with vaseline and in those in carbon dioxide atmosphere. The greater deviations from normal in the stems experimented with were due, it is safe

to conclude, to injury and to loss of turgidity, but in no case could the bends be interpreted as reversed curvatures.

Roots in Ammonia Vapor Atmosphere

For the experiments with roots in ammonia vapor atmosphere, *Zea mays* and *Vicia Faba* seedlings were used. *Zea mays* roots were used for testing for strength of ammonia solution which would not cause noticeable injury. Four-sided glass jars of 1750 c.c. capacity were lined with moist absorbent paper. In these jars were fastened corn seedlings with roots four centimeters long. In one of these jars were poured five cubic centimeters of five-tenths per cent of twelfth normal ammonia solution, in a second the same amount of twenty-five hundredths per cent, in the third twelve hundredths per cent, in a fourth six hundredths per cent, and in a fifth three hundredths per cent. The roots in the five hundredths per cent atmosphere were browned for about five millimeters; the roots in twenty-five hundredths atmosphere were apparently uninjured after fifteen hours, but the atmosphere tested alkaline with moistened litmus paper. Ammonia solutions of twenty-five hundredths per cent and twelve hundredths per cent were used for testing further; the weaker was renewed twice as often as the stronger, each time with the addition of two cubic centimeters. Corn grains with the roots just emerging were placed on a support and five cubic centimeters of twelve hundredths per cent ammonia solution were put in at first. The atmosphere was renewed every five to six hours. The litmus paper, red when put in, soon changed to blue and remained blue. The roots here showed normal geotropism.

In the twenty-five hundredths per cent atmosphere, the roots, if left for more than twenty-four hours, became brown. During the first few hours, however, before injury was evident, they had remained horizontal as compared with positive geotropism in the twelve hundredths per cent atmosphere. After twenty-four hours some of the roots showed horizontal bends and some of them had grown in two or three directions, as though they were uncomfortable. When the roots were uninjured, the response

was normal; when they were horizontal or curved abnormally, they had not grown or they were injured by the ammonia.

Vicia Faba roots were the ones Small found to show the best results, and so a series of experiments with these seedlings was performed. The method used was the same as the method just described for *Zea mays*. Seedlings with roots one to three centimeters long were put into jars of 1750 c.c. capacity, containing ammonia solution of twelve hundredths per cent and twenty-five hundredths per cent. In a weaker atmosphere the roots were uninjured and showed normal geotropic response, but in the stronger atmosphere they remained horizontal and did not grow. If left in for a period longer than twenty-four hours they became brown. In the atmosphere from twenty-five hundredths per cent ammonia solution, both with *Zea mays* and *Vicia Faba*, there was no growth in most cases, and so there could be no curvature, while in the twelve hundredths per cent atmosphere the growth was almost normal. In two of the experiments using twenty-five hundredths per cent ammonia, there was slight growth and slight downward curvature of the roots.

The *Vicia Faba* experiments for roots were ten in number: five including twenty-eight seedlings in twenty-five hundredths per cent ammonia hydrate atmosphere, and five including twenty-four seedlings in twelve hundredths. The roots were from one to four centimeters long when set up. Growth in the vapor from the stronger solution was only one or two centimeters or none at all in two days; in the vapor from the weaker solution the growth was as much as four centimeters in two days.

SUMMARY

A series of experiments attempting to get reversal of geotropic response was undertaken because of doubt as to the correct interpretation of Small's and Rea's and Lynn's results in the experiments in which they record reversed curvatures.

The experiments include the employment of acetic acid vapor, vaseline coating, olive oil coating, and carbon dioxide atmosphere for stems; and ammonia vapor for roots. Young seedlings were used and placed horizontally in the dark.

Acetic acid vapor was found to have no effect in changing the geotropic response of stems. Stems uninjured, but in an atmosphere testing acid, showed normal, negative geotropism, but those in stronger atmosphere grew very little or not at all and bent upward only very slightly, remained horizontal, or showed erratic bendings varying individually.

Vaseline and olive oil coating for stems, supposed to keep in the carbon dioxide of respiration, and make the stems acid, prevented normal curvature only when inhibiting growth or causing injury. Long *Helianthus annuus* and *Lupinus albus* stems sagged, but bent upward near the upper end. Long *Zea mays* stems remained horizontal, having exhausted the food supply in the grain. There were no curvatures that could be interpreted as reversals of geotropic response.

Stems in carbon dioxide atmosphere showed upward curvatures with the angles proportionate to the rate and amount of growth. Where growth was inhibited, there was no curvature in the shorter stems, and in the longer ones there were gravity sags. In longer stems showing some growth there was a region of upward bending near the cotyledons.

Roots in the ammonia vapor behaved much like stems in acetic acid vapor, with the curves normal when no injury was present. The roots exhibited normal geotropic response in the jars containing twelve hundredths per cent solution, which was strong enough to test alkaline, but weak enough not to cause injury. In twenty-five hundredths per cent atmosphere growth was almost entirely inhibited. Here the seedlings remained horizontal or showed injury and curved abnormally in hooks and turns, but not geotropically.

Sufficient attempts were made to obtain reversed curvatures if they were to be obtained. The failure to get them, as Small and Rea and Lynn claimed in similar experiments, was, most likely, due to the difference in interpretation of the data of experimental results — the interpretation of the physiological behavior of the seedlings in the acid and alkaline atmospheres.

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EXPLANATION OF PLATES

PLATE XVI

Fig. 1. *Helianthus annuus* stems left in carbon dioxide of sixteen per cent (at left) and of eighteen per cent (at right) for forty-eight hours. One short stem is horizontal; others contain upward curvatures with long bending regions; some sag, but curve up near cotyledons.

Fig. 2. *Helianthus annuus* stems left in fourteen per cent carbon dioxide for forty-eight hours (at right). Growth was two centimeters. Shorter stems show decided negative curvature; longer stems sag. Control stems (at left) show sharp negative bends near the soil.

PLATE XVII

Fig. 1. *Helianthus annuus* stems which had been coated with vaseline and left in the dark three days in vertical and one day in horizontal position. (Note similarity to long control stems shown in Fig. 2.) There is a long region of curvature, but negative geotropism. Some have turned over after curving up. Some have fallen over by gravity after they had made upward curves, thus simulating positive geotropic curves.

Fig. 2. Controls for *Helianthus annuus* stems nine to twelve centimeters long. These were left for forty-eight hours in the dark in a horizontal position. Note long bending region, and horizontal turns due to weight. Some have turned over after having bent upward.

PLATE XVI

Fig. 1

Fig. 2

PLATE XVII

FIG. 1

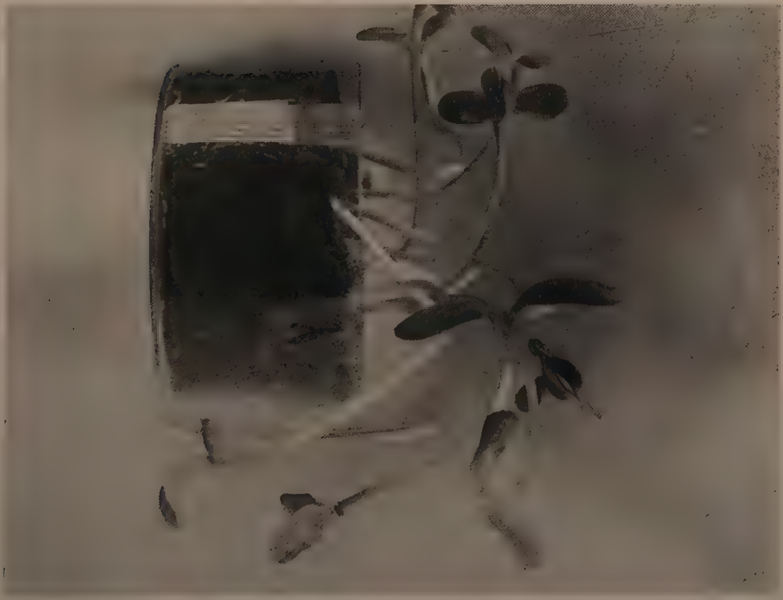

FIG. 2

THE LIFE-HISTORY OF A NEW HOMO-THALLIC MUCOR*

BESSIE BERNICE KANOUSE

The curious fact that nearly all the known species of the genus Mucor are heterothallic makes the finding of a new homothallic species of more than ordinary interest. The modern studies of Blakeslee indicate that only one of the latter species is well known, viz., *Mucor genevensis*, and that very little reliance can be placed on the older records of such species.

On January 17, 1922, such a Mucor was isolated from fresh horse dung which had been obtained from a stable in the vicinity of Ann Arbor. From an initial gross transfer, spores were sprayed upon agar, and in due time three single germinating spores were cut out of agar and transferred to sterilized bread in glass capsules. The three capsules were marked A, B, and C respectively. Culture A, however, was soon lost. The material from the single spore C was subcultured and studied, while that from B was set aside for class use.

About two months later, zygospores were found in some subcultures of both B and C. The discovery of zygospores suggested a homothallic Mucor. It seemed desirable, therefore, to make some further studies.

The fungus was cultured on various kinds of media including the following: bread, oatmeal agar, corn meal agar, and Blakeslee's synthetic agar. By far the best results for the zygospore formation were obtained in the cultures on Blakeslee's agar. Upon this medium zygospores were formed in such numbers in cultures five to seven days old that they gave a reddish-brown color to the surface of the agar. The coloration could be seen easily without the aid of a lens when the scant mycelial growth

* These studies were made under the direction of Dr. C. H. Kauffman.

was pushed away. Azygospores were also numerous in cultures grown on some of the other media; under these conditions, however, the fungus produced fewer zygospores and a proportionately greater number of sporangia and a taller turf.

As a standard culture medium, fresh white bread was found desirable with reference to the development of the morphological characteristics of the fungus. Bread, slightly moistened, was placed in large glass capsules and sterilized in an autoclave for twenty minutes at fifteen pounds pressure. After the transfer of spores to the bread, the cultures were placed in an incubator at 25° C. At this temperature it was found that zygospores would form abundantly within four days. The following description was made from such cultures.

The aerial turf is less than three cm. in height. It is white in mass in the early stages of development, becoming "drab gray" to "smoky gray" (Ridg.). The delicate hyphae contain gray, granular protoplasm, oil particles and other inclusions. The protoplasm in or near the suspensors is often very dense and distinctly golden brown or bright orange. On Blakeslee's agar in young cultures the colors are decidedly brilliant. The protoplasm may even be tinted a distinct rose pink.

The sporangiophores branch sympodially (Plate XVIII, Fig. 1). The branches of the sporangiophore with the exception of the youngest, are cut off by a basal cross-wall. The portion of the sporangiophore branch above the wall becomes nearly devoid of protoplasm by the time its apical sporangium has been formed (Fig. 2). In old mycelium cross-walls are frequently found scattered irregularly.

The sporangia are borne either terminally on sporangiophores or on the ends of the branching hyphae (Fig. 1). They are spherical and measure 30–52 μ in diameter (Fig. 5). The sporangium wall is smooth. It is very fragile and is broken away easily, leaving only a small irregular ring at the base of the columella. The sporangium wall is attached to the columella only at the point of union of the sporangiophore and columella. The columellae are mainly spherical, sometimes slightly oval, quite uniform and without extreme variation in shape; they

measure 20–48 μ in diameter (Fig. 4). The sporangiospores are small and hyaline, measuring $4–6.5 \times 2.5–3.5$ μ. The smaller ones are oval to spherical in shape, while the larger ones are elliptical (Fig. 6).

Chlamydospores and oidiospores are also formed. The former are frequent and occur in the vegetative mycelium near the surface of or within the substratum. At maturity they become easily detached from their hyphae. Sometimes they are joined in chains of five to six, but more commonly appear either singly or in two's. They are usually ellipsoidal, provided with thick walls and a densely granular, gray protoplasmic content (Fig. 3). What may be called oidiospores are less frequently seen. They differ from the chlamydospores chiefly in having thinner walls. Their shape and size are rather unusual for this type of mycelial variation and the content is pale gray in color (Fig. 3c).

Zygospores are formed as a result of the fusion of two gametangia of unequal size. The gametangia are cut off from the ends of the suspensors by cross-walls in the usual way. The suspensors also vary in size and shape, depending in part upon the point of origin on the hyphae; they are sometimes long and club-shaped, as is the case when the ends of two hyphae unite. They may be very short and thick, or may even be so swollen as to be almost spherical (Figs. 7–10).

The suspensors may originate from two parallel hyphae (Fig. 7), or the tip of a free hypha may conjugate with the side of another hypha (Fig. 9). Sometimes conjugation occurs between the ends of two hyphae from entirely different sources (Fig. 10). The most definite proof of the homothallic character of this species is in cases where the tip of one hypha turns toward its own supporting hypha to form the zygospore (Fig. 11). When a gametangium is formed on or near the end of a hypha, the latter usually produces a short-pointed prolongation, presenting a condition much like what one observes in zygospore formation in Zygorhynchus (Fig. 8). The prolongation is sometimes long and slender, at other times short and stout. It is frequently filled with dense protoplasm colored as described above for the suspensors.

The zygospores are unusually small as compared with those of many Mucors. Their size ranges from $65 \times 65\ \mu$ to $18 \times 20\ \mu$. They are spherical in shape with those portions to which the suspensors are attached slightly flattened. The golden-brown exospore is covered with pointed, warty excrescences that give to the surface of the zygospore an elaborately sculptured appearance of a definite pattern (Plate XIX, Figs. 12–13).

The internal development of the zygospores can to a certain extent be studied in the living material, as was done by Brefeld (3) in some species. This is the more easily accomplished because the exospores of this species are readily removed so that the contents, still surrounded by the inner wall or walls, can be seen with remarkable clearness.

A slight pressure of the cover glass on a water mount breaks away the outer wall, leaving the interior intact. The whole process can be watched under the microscope. Figures 15a to 15j show, after such removal of the exospore, various conditions of the protoplasm and its distribution as well as the vacuolization and the oil globules. As far as could be determined, these conditions at different stages of maturity agree with the cytological evidence of the protoplasmic changes, as published by Miss Keene (4).

In zygosporic material two weeks old, it is possible to find zygospores in various stages of development. The younger zygospores possess a cytoplasmic structure that is finely divided and is evenly distributed throughout the zygospore. A zonation soon appears, however, separating the central mass of globular reticulate material from the outer layer of cytoplasm. These globules appear like fusions of the smaller particles. The fusions appear to take place first in the center, and to continue outward until the entire zygospore is filled with large foam-like structures. The contents of the globules are highly refractory.

The globules evidently fuse rapidly, for in cultures two weeks old this condition has disappeared in the majority of the zygospores, and a large centrally placed oil globule nearly fills the zygospore. A thin layer of protoplasm surrounds the oil globule.

This condition is found also in zygospores three months old. But in zygospores twelve months old, left in cultures which had gradually dried up, the walls inside the exospore are very much thicker than in the cases previously mentioned; the protoplasm has been drawn away from the walls, presumably by loss of water, although it still encloses a large oil globule. This oil globule is only slightly smaller than in zygospores only two weeks old (Fig. 15j).

Azygospores are formed when the conditions are favorable for the maximum production of zygospores. They are smaller in size than the true zygospores, but the outer wall has the same curious markings and golden-brown color that is present in the zygospore (Fig. 14). They are formed on the ends of hyphae, or arise from an almost indistinguishable suspensor growing directly from the side of a hypha. By careful manipulation of a microscopic mount, it was easy to determine the fact that only one suspensor had been attached to the azygospore. The absence of the point of attachment is as conspicuous as is its presence.

Soon after zygospores were found in cultures B and C, a new single spore culture was made from the B culture. The new culture was designated culture D. It was expected that zygospores would be produced in this subculture under the conditions previously found favorable in the other cultures. But no zygospores were formed in this new subculture D, nor in any of the cultures of this strain. In all respects excepting only that of zygospore formation, the plants of strain D correspond to those of cultures B and C. A consideration of the behavior of culture D, and of similar cases reported by Blakeslee, may help to explain some of the characteristics that have appeared regularly in the cultures B and C. These characteristics are found both in cultures only a few days old when a good food supply is available, and in older cultures as well. The stimulus due to mycelial contact is present and results at times in the production of gametangia-like organs, but their ability to fuse and form zygospores is apparently absent (Fig. 16). These gametangia and their suspensors differ from the normal organs

in that all parts are poorly nourished, are quite vacuolate, and remain partially hyaline.

Such forms are similar to the imperfect hybridization figures published by Blakeslee (1), showing the interactions between *Mucor* (V) and *Zygorhynchus heterogamus*, when grown together in culture. In another paper Blakeslee (2) has shown that certain variations obtained from homothallic *Mucor genevensis* show unmistakable evidences of reacting as a plus race when grown opposite a known minus race. From this it seems clear that bisexuality is not a fixed characteristic of all the spores formed in a sporangium of these two homothallic Mucors. The balance of sexuality may be so unequal that a decided either plus or minus factor prevails in some of the spores. It is entirely probable that strain D originated from and represents such a spore, and that plants from spores similar to strain D are present in cultures B and C. This would account for the peculiar half-formed reproductive organs present due to the interaction between mycelium from the type of plant strain D and the mycelium of the bisexual spores (Fig. 16). If it is found that the loss of homothallism remains as a constant character, then strain D may be called a mutation.

When it was found that this Mucor was a homothallic species, it seemed probable that it might be *Mucor genevensis* Lendner. Through the kindness of Dr. Blakeslee, who sent us a culture of *Mucor genevensis*, it has been possible to compare the two species. The species at hand differs at once from *Mucor genevensis* in the size of the zygospores, and in the fact that the gametangia are heterogamic, while in *Mucor genevensis* the gametangia are isogamic.

The Mucor sent by Dr. Blakeslee as *Mucor genevensis* corresponds to the description given by Lendner (5) for *Mucor genevensis*, in which the measurement of the zygospores is given as 100 μ in diameter, whereas even the maximum size for our species is only 65 μ. The sporangiospore size also differs greatly. In *Mucor genevensis* the spores are 9–10 μ as compared with 3–5 μ in our cultures of B, C and D. There is also a difference in the shape of the spore and a decided difference in that of the

columella. The columella of *Mucor genevensis* is for the most part of the panduriform type. The panduriform type of columella is never seen in this species of Mucor.

From a comparison of *Mucor genevensis* with the Mucor described in this paper, it seems entirely clear that an undescribed species of homothallic Mucor has been found. The name **Mucor parvispora,** sp. nov., is therefore proposed for this species.

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DESCRIPTION OF PLATES

PLATE XVIII

Fig. 1. Habit sketch of sporangiophore showing branching.
Fig. 2. Portion of sporangiophore showing distribution of protoplasm and position of cell wall.
Figs. 3–5. A sexual reproduction.
  Figs. 3a–b. Chlamydospores.
  Fig. 3c. Oidiospores.
  Figs. 4a–b. Two types of columella showing "free" attachment of sporangium wall.
  Fig. 5a. Young sporangium.
  Fig. 5b. Sporangia fully developed.
Fig. 6. Sporangiospores.
Figs. 7–11. Development of zygospores and manner of attachment of suspensors to hyphae.
  Figs. 7–9. Early stage in zygospore formation.
  Fig. 10. Full-sized zygospore.
  Fig. 11. Full-sized zygospore formed on a single hypha.

PLATE XIX

Figs. 12–13. Appearance of exospore and attachment of suspensors.
  Fig. 12a. Fully developed zygospore showing in detail characteristic markings.
  Fig. 12b. Detail of star-shaped thickening of the exospore viewed at different angles.
  Figs. 13a–b–c. Attachment of suspensors.
Fig. 14. Azygospore.
Fig. 15. The internal structure of zygospore with exospore removed.
  Figs. 15a–b. Early stages in development of globular cytoplasmic structures.
  Figs. 15c–e. Later stages showing condition after fusion of smaller particles into globular reticulate masses.
  Fig. 15f. State in which large cytoplasmic globules fill the entire space.
  Figs. 15g–h. Final accumulation of oil in one centrally-placed globule.
  Fig. 15i. Younger stage of 15h.
  Fig. 15j. Zygospore twelve months old showing thickened wall and contraction of protoplasm.
Fig. 16. Imperfect hybridization between mycelium represented by strain D and mycelium from bisexual spores.
  Figs. 16a–b. Mycelial contact without formation of gametes.
  Figs. 16c–d–e–f. Arrested zygospore development.
Fig. 17. Abnormal conditions found in sporangiophores.

PLATE XVIII

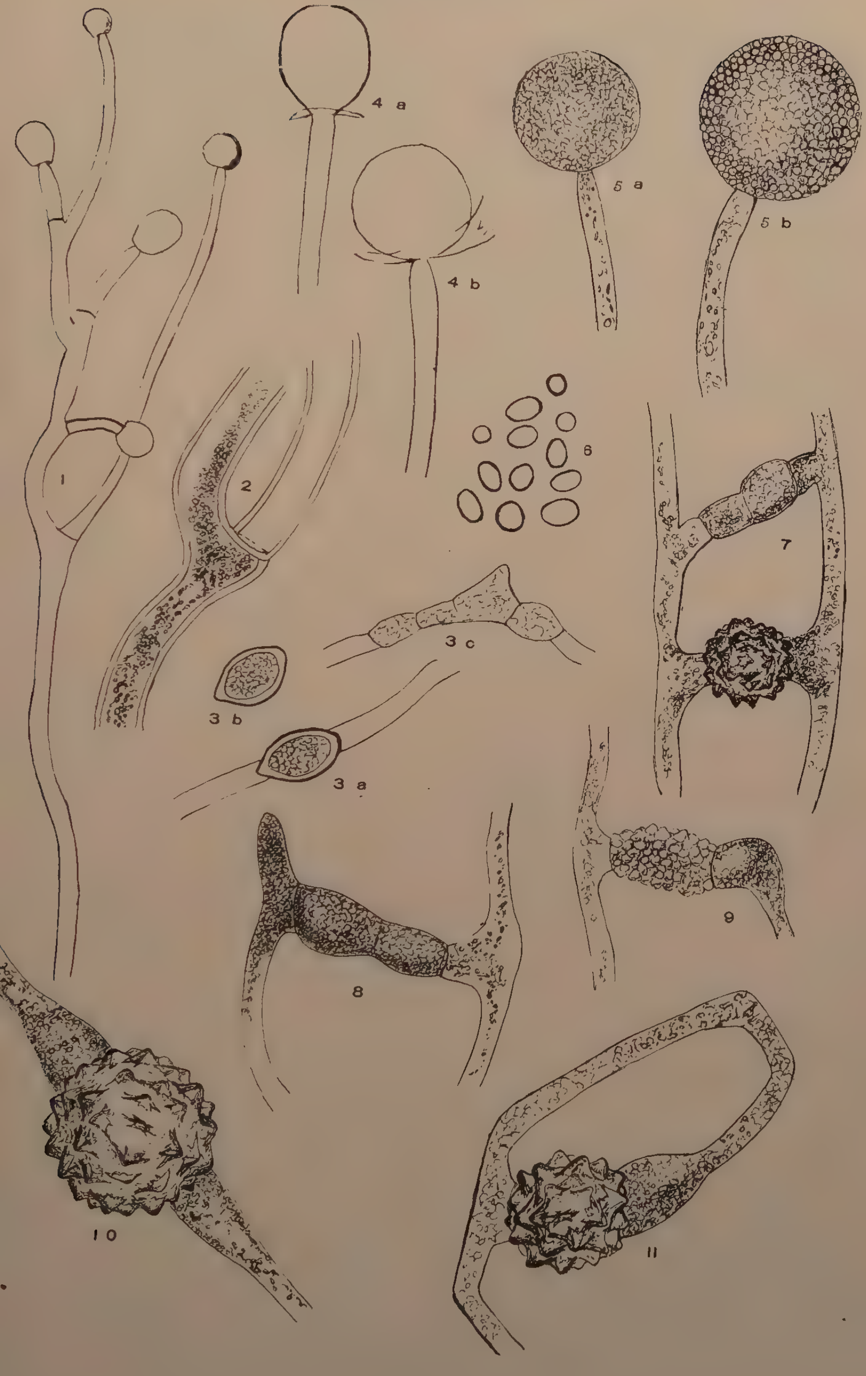
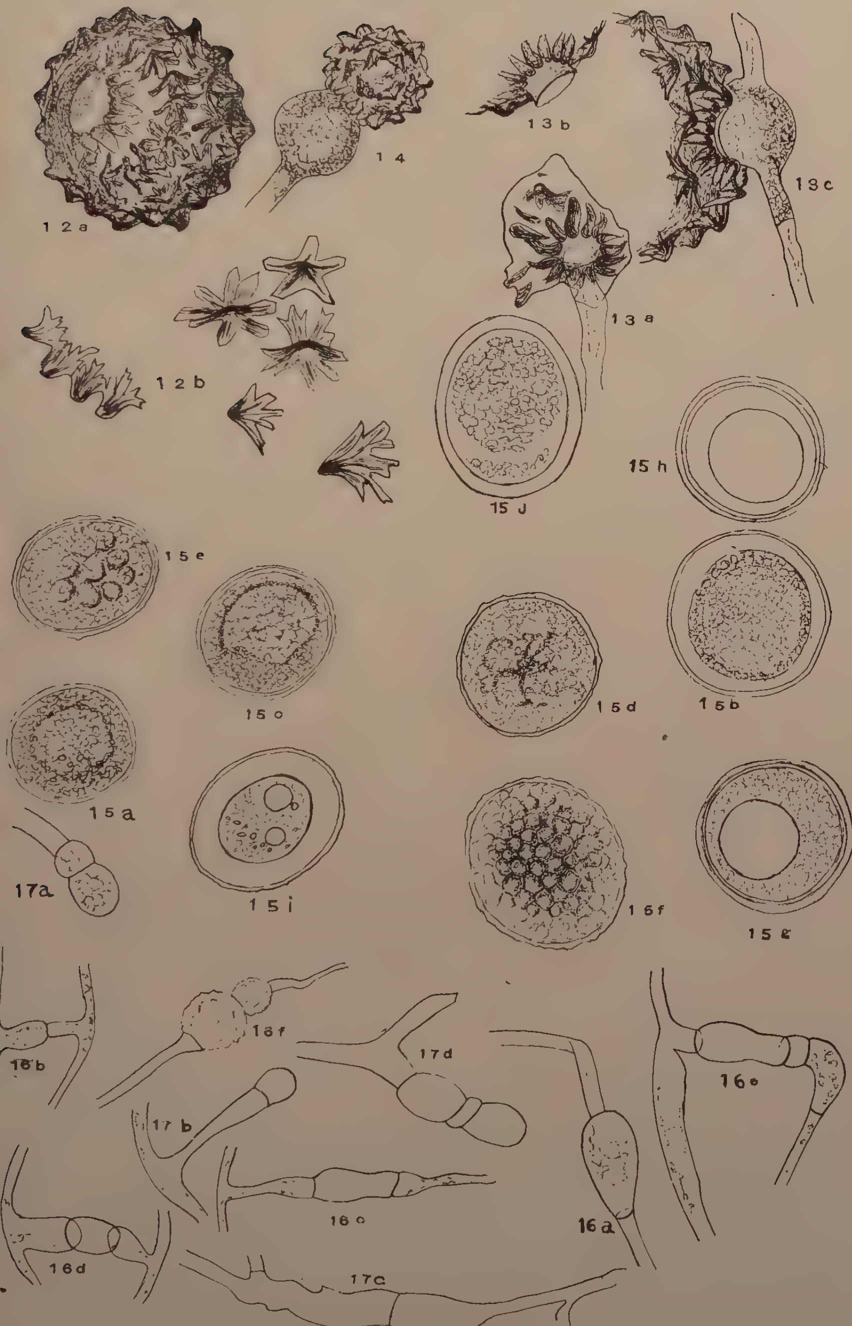


PLATE XIX



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16 d
17c

DISTRIBUTION OF THE UMBELLALES IN MICHIGAN *

L. A. KENOYER

THERE have been reported from Michigan 59 species belonging to the order Umbellales. Of these 45 are natives of the state; 13 members of the Carrot Family have been introduced from the Old World; one Aralia has come from the states south of us.

The order is divided into three families: Araliaceae (Ginseng Family) with 7 species in Michigan, Ammiaceae or Umbelliferae (Carrot Family) with 29 native and 13 introduced species, and Cornaceae (Dogwood Family) with 10 species.

Of 82 species of native Umbellales described in Britton & Brown's *Illustrated Flora of the Northern States and Canada*, 45, or about 55 per cent, are found in Michigan. They may be classified as follows as regards the region of North America which they occupy:

	Listed in Britton & Brown	Found in Michigan
Eastern species	48	32
Western species	18	3
Northern species	11	9
Southern species	4	0
Continent-wide species	1	1

* In the preparation of this and the following paper, the writer has consulted the herbaria of the Michigan Agricultural College, the University of Michigan, the Field Museum in Chicago, the private herbaria of Messrs. B. A. Walpole and C. Billington, and all available distribution lists, including one furnished for the purpose by Mr. C. W. Fallass. He is indebted to Prof. H. T. Darlington for helpful suggestions. The nomenclature of Britton & Brown's *Illustrated Flora* is followed except for that portion of the Ericales which is covered by the portions issued to date of the later *North American Flora* issued from the New York Botanical Gardens.

Three of the nine northern species found in Michigan are really northeastern and are not, therefore, especially prominent in the Upper Peninsula. This peninsula, therefore, does not have a large representation from the order. Of the 59 reported species 27, or almost half, have not been reported from the Upper Peninsula. On our list we have 6.5 times as many localities reported for the species of this order in the Lower as in the Upper Peninsula. The Araliaceae are all eastern species except one, the rare *Echinopanax horridum*, mentioned later, which is western. The Ammiaceae are predominantly eastern, but include northern and western species and the continent-wide *Heracleum lanatum*. The statement regarding the relative scarcity of Umbellales in the Upper Peninsula is especially true of this family. The Cornaceae include 6 eastern and 4 northern species.

A study of the ecological distribution of the members of this order reveals the fact that of the native representatives 14 are found mainly in swamps and bogs, 16 mainly in pioneer or subclimax forests, 13 mainly in climax forests, while 2 belong to the prairies. Their ecological range is wide, and their representation in the climax formation larger, perhaps, than is that of most orders.

Of the three families the one most strikingly represented in the climax forest is the Araliaceae, 5 of the 6 native species occurring in this habitat. The other species, *Aralia hispida*, is commonly found in subclimax situations, particularly in secondary successions following burns. The Ammiaceae include 10 swamp representatives, which belong to the prairie swamp type rather than to the bog type. This family also contains 2 prairie species, represented in the southern counties, 4 to 6 subclimax forest species, and 10 to 12 climax forest species. Conspicuous among the latter are the 4 species of Sanicula and the 4 of Washingtonia. The Cornaceae belong to pioneer and subclimax rather than to climax formations. *Chamaepericlymenum canadense* and *Nyssa sylvatica* are swamp forms. Most of the species of Cornus are found in swamps, on dunes, along stream borders, and in other subclimax habitats.

One species of the Ginseng Family, *Echinopanax horridum*, has been found only on Isle Royale. The nearest known station for the plant outside this island is the Montana Rockies. *Aralia spinosa* has been found in three counties as an escape from cultivation. Its northern native limit is Ohio.

Of the introduced species of the Carrot Family at least four have become quite general in their distribution, viz., the caraway (*Carum carui*), the poison hemlock (*Conium maculatum*), the carrot (*Daucus carota*), and the parsnip (*Pastinaca sativa*). Six others have been found only locally or occasionally. They are *Aegopodium podagraria*, *Anethum graveolens*, *Coriandrum sativum*, *Foeniculum foeniculum*, *Hipposelinum levisticum* and *Imperatoria ostruthium*. Coriandrum has been reported only from Detroit, where it was found on the streets, and Anethum only from Berrien County as a weed in cornfields. I have seen no specimen of Imperatoria from Michigan. The three remaining species, *Carum copticum*, *Pimpinella anisum* and *Torilis nodosa*, have been found only spasmodically by O. A. Farwell on ballast in Detroit.

Of the native species 9 are of widespread distribution, 18 are restricted to the south and 2 are restricted to the north. I have not seen *Pleiotaenia nuttallii*, one of the southern forms, nor have I definite reports of its occurrence, although it is assigned to Michigan by both the Gray and the Britton & Brown manuals. It is a prairie form which is found to the south and west of us, so it may have existed in Michigan before the prairie land became scarce. I have not seen *Zizia cordata*. It is reported from Genesee, Cass and Kent counties, but quite probably all these reports refer to the very similar *Thaspium trifoliatum*. *Thaspium barbinode* is an extreme southern species of limited distribution. *Eryngium aquaticum* is a plant of the western prairies, and occurs only in 3 or 4 of our southwestern counties. The species restricted to the north are two woodland ones, — *Washingtonia divaricata* and *W. obtusa*. The latter, a Canadian plant, was reported from Gogebic County, in our extreme northwest, by Prof. Darlington.

Five species of the Dogwood Family are of general distribu-

tion and five are more southern in range. *Cornus asperifolia* is apparently of rare occurrence, being reported from but five counties, mainly southeastern. The flowering dogwood (*Cynoxylon floridum*) and the black gum (*Nyssa sylvatica*) are distinctly southern, being restricted to the southern half of the Lower Peninsula.

UMBELLALES

Flowers regular, usually perfect; disk adherent to the inferior and usually 2-carpellary and 2-celled ovary; ovules 1 in each cell; flowers usually in umbels (except in Cornaceae).

Fruit fleshy.
  Fruit a berry..........................1. *Araliaceae* (*Ginseng Family*).
  Fruit a drupe..........................3. *Cornaceae* (*Dogwood Family*).
Fruit dry, splitting when ripe into 2 1-seeded carpels
  2. *Ammiaceae* (*Carrot Family*).

I. *ARALIACEAE* (Ginseng Family).

Leaves compound.
  Leaves decompound, alternate; styles 5..............1. *Aralia*.
  Leaves palmately compound, whorled; styles 2–3......2. *Panax*.
Leaves simple, palmately lobed; styles 2...............3. *Echinopanax*.

1. Aralia [Tourn.] L.

Umbels numerous in a large panicle.
  Spiny shrub or tree.................................1. *A. spinosa*.
  Unarmed herb..2. *A. racemosa*.
Umbels 2–7 or more, corymbed.
  Plant nearly smooth; leaf and scape arising from rootstalk
  3. *A. nudicaulis*.
  Plant hairy or bristly..............................4. *A. hispida*.

1. *Aralia spinosa* L. ('full of spines')
   Hercules Club, Angelica, Spikenard Tree.
   Escaped from cultivation. Native in Indiana and southward.

Specimens examined. — Charlevoix Co. (S. S. Smith, 1915); Washtenaw Co. (E. C. Allmendinger).

Reported from Wayne Co. (O. A. Farwell).

2. *Aralia racemosa* L. ('with flowers in racemes')
American Spikenard, Indian Root.
All over the state, mainly in climax (beech-maple) forests.

Specimens examined. — Cass Co. (H. S. Pepoon); Washtenaw Co. (B. A. Walpole, 1919); Wayne Co. (C. Billington, 1919); Ingham Co. (1865); Oakland Co. (C. Billington, 1919); Genesee Co. (D. Clark); St. Clair Co. (C. K. Dodge); Gratiot Co. (C. A. Davis); Newaygo Co. (E. A. Bessey, 1916); Mason Co. (R. W. Chaney, 1910); Roscommon Co. (Bessey & Darlington, 1916); Charlevoix Co. (E. A. Bessey, 1912); Cheboygan Co. (F. C. Gates, 1911); Mackinac Is. (C. F. Millspaugh, 1898); Alger Co. (C. F. Wheeler, 1900); Marquette Co. (B. Barlow, 1901); Gogebic Co. (H. T. Darlington, 1919).

Reported from Magician Lake region (H. S. Pepoon); St. Joseph Co. (F. P. Daniels); Calhoun Co. (C. E. Barr); Barry Co. (H. T. Darlington); Kent Co. (Emma J. Cole); Tuscola Co. (C. K. Dodge); Huron Co. (C. A. Davis); Charity Islands (C. K. Dodge); Mecosta Co., Clare Co. (E. A. Bessey); Bay Co. to Mackinac Co. along coast (C. K. Dodge); Alpena Co., Montmorency Co. (H. T. Darlington); Manistee Co. (F. P. Daniels); Emmet Co. (C. E. Barr); Beaver Island (H. T. Darlington); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons); Ontonagon Co. (H. T. Darlington); Keweenaw Co. (O. A. Farwell).

3. *Aralia nudicaulis* L. ('with naked stem')
Wild or Virginian Sarsaparilla.
All over the state, mainly in climax beech-maple forests.

Specimens examined. — Berrien Co. (O. E. Lansing, Jr., 1911); St. Joseph Co. (A. B. Burgess, 1903); Jackson Co. (S. H. & D. R. Camp, 1898); Washtenaw Co. (A. J. Peters, 1894); Ingham Co. (L. J. Cole, 1895); Oakland Co. (C. Billington, 1914); St. Clair Co. (C. K. Dodge, 1899); Muskegon Co. (C. D. McLouth, 1896); Gratiot Co. (C. A. Davis, 1891); Newaygo Co. (E. J. Ford, 1914); Mason Co. (R. W. Chaney, 1910); Missaukee Co. (C. J. O'Dell, 1914); Antrim Co. (Wm.

Kooyer, 1914); Charlevoix Co. (E. A. Bessey, 1912); Cheboygan Co. (F. C. Gates, 1911); Emmet Co. (F. C. Gates, 1917); Mackinac Co. (J. H. Ehlers, 1920); Alger Co. (J. G. Coulter, 1892); Marquette Co. (Bronson Barlow, 1901); Baraga Co. (S. R. Bailey, 1893); Gogebic Co. (E. A. Bessey, 1919); Keweenaw Co. (O. A. Farwell, 1886); Isle Royale (A. E. Foote, 1868).

Reported from Magician Lake region (H. S. Pepoon); Hillsdale Co., Kalamazoo Co. (M. A. C. identification); Calhoun Co. (C. E. Barr); Wayne Co. (John M. Sutton); Ottawa Co. (M. A. C. identification); Kent Co. (Emma J. Cole); Ionia Co., Montcalm Co. (M. A. C. identification); Tuscola Co. (C. K. Dodge); Huron Co. (C. A. Davis); Charity Islands (C. K. Dodge); Bay Co. to Mackinac Co. along coast (C. K. Dodge); Osceola Co. (H. T. Darlington); Clare Co. (E. A. Bessey); Manistee Co. (L. H. Harvey); Benzie Co. (W. G. Waterman); Leelenau Co. (E. A. Bessey); Otsego Co. (M. A. C. identification); Beaver Island (H. T. Darlington); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Ontonagon Co. (H. T. Darlington).

4. *Aralia hispida* Vent. ('bristly')

Bristly Sarsaparilla; Wild Elder.

A pioneer shrub in sandy ground, often in burn successions.

Specimens examined. — Van Buren Co. (H. S. Pepoon, 1904); Ingham Co. (1887); St. Clair Co. (C. K. Dodge, 1896); Gratiot Co. (C. A. Davis, 1893); Oceana Co. (D. Cooley, 1846); Mason Co. (R. W. Chaney, 1910); Missaukee Co. (E. A. Bessey, 1916); Roscommon Co. (Bessey & Darlington, 1916); Cheboygan Co. (F. C. Gates, 1911); Mackinac Is. (C. F. Millspaugh, 1898); Marquette Co. (B. Barlow, 1901); Gogebic Co. (Bessey & Darlington, 1919); Keweenaw Co. (F. E. Wood, 1883); Isle Royale (A. E. Foote).

Reported from Hillsdale Co. (M. A. C. identification); Washtenaw Co. (W. J. Beal); Oakland Co. (J. W. Stacey); Kent Co. (Emma J. Cole); Muskegon Co. (C. D. McLouth); Huron Co. (C. A. Davis); Tuscola Co. (C. K. Dodge); Bay

Co. to Mackinac Co. along coast (C. K. Dodge); Gladwin Co. (M. A. C. identification); Manistee Co. (F. P. Daniels); Emmet Co. (Fallass & Swift); Beaver Island (H. T. Darlington); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons); Ontonagon Co. (H. T. Darlington).

2. Panax L. Ginseng

(Greek, 'all-healing')

Leaflets 5, ovate or obovate, stalked, acuminate......1. *P. quinquefolium*
Leaflets 3–5, more narrow, sessile, obtuse.............2. *P. trifolium*.

1. *Panax quinquefolium* L. ('five-leaved')

Ginseng, Red Berry, Sang.

Rich climax (beech-maple) woodlands, almost confined to Lower Peninsula. Scarce in jack-pine region. Once abundant, but becoming rather rare because of the medicinal employment of the root.

Specimens examined. — Cass Co. (H. S. Pepoon, 1906); Lenawee Co. (Lacy, 1914); Jackson Co. (1838); Washtenaw Co. (B. A. Walpole, 1918); Ingham Co. (1887); Oakland Co. (B. F. Chandler 1916); Macomb Co. (D. Cooley, 1843); Ottawa Co. (C. Billington, 1914); Genesee Co. (D. Clark); St. Clair Co. (C. K. Dodge, 1896); Charlevoix Co. (E. A. Bessey, 1912).

Reported from Van Buren Co. (L. H. Bailey); Calhoun Co. (C. E. Barr); Wayne Co. (C. Billington); Kent Co. (Emma J. Cole); Ionia Co. (W. J. Beal); Montcalm Co. (W. J. Beal); Huron Co. (C. K. Dodge); Mason Co. (W. J. Beal); Otsego Co. (E. A. Bessey); Cheboygan Co. (M. A. C. identification); Emmet Co. (Fallass & Swift); Chippewa Co. (W. J. Beal).

2. *Panax trifolium* L. ('three-leaved')

Dwarf Ginseng; Groundnut.

All parts of the state in climax (beech-maple) woods.

Specimens examined. — Cass Co. (H. S. Pepoon, 1903); Jackson Co. (S. H. & D. R. Camp, 1897); Washtenaw Co.

(A. J. Pieters, 1892); Wayne Co. (C. Billington, 1914); Ingham Co. (1865); Oakland Co. (C. Billington, 1915); St. Clair Co. (C. K. Dodge, 1898); Schoolcraft Co. (W. T. S. Cornell, 1916); Marquette Co. (B. Barlow, 1901); Keweenaw Co. (F. E. Wood, 1883).

Reported from Calhoun Co. (C. E. Barr); Kent Co. (Emma J. Cole); Muskegon Co. (C. D. McLouth); Tuscola Co., Huron Co. (C. A. Davis); Mecosta Co. (C. W. Fallass); Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels).

3. Echinopanax Decne.

(Greek, '*prickly Panax*')

Echinopanax horridum (J. E. Smith) Decne. ('prickly')
Fatsia horrida B. & H.
Devil's Club.

Reported from Isle Royale (W. A. Wheeler, 1901, two localities; W. S. Cooper, 1914, two other localities). Climax (fir-birch-spruce) forest. The nearest known station for the plant outside this island is the Montana Rockies.

II. *AMMIACEAE* (Carrot Family)[1]

(Umbelliferae)

KEY BASED ON FRUIT CHARACTERS

A. Fruit armed with stiff prickles.
  Prickles hooked; leaves palmately lobed..........2. *Sanicula.*
  Prickles barbed; leaves 2–3-pinnate..............3. *Daucus.*
A. Fruit without prickles.
  Fruit ribless; flowers in heads....................1. *Eryngium.*
  Fruit ribbed; flowers in umbels.
    B. Fruit several times longer than wide.
      Fruit bristly along the ribs................4. *Washingtonia.*
      Fruit not bristly.
        Annual herbs with decompound leaves...5. *Chaerophyllum.*
        Perennial herbs with 3-foliolate leaves...6. *Deringa.*

[1] The following introduced species, being of sporadic occurrence, are not included in the key.

Anethum graveolens L., Dill, closely resembles *Foeniculum foeniculum* in appearance, but has the fruits strongly flattened dorsally. Specimen

B. Fruit not more than twice as long as wide.
  C. Fruit flattened laterally.
    D. Length of fruit no greater than width.
      E. Carpels strongly flattened laterally.
        Leaves simple . . . . 20. *Hydrocotyle.*
        Leaves ternately decompound, 21. *Erigenia.*
      E. Carpels terete or nearly so.
        Seed face concave . . . . 22. *Conium.*
        Seed face flat.
          Leaves decompound; oil tubes solitary in intervals between ribs of fruit . . . . . 26. *Cicuta.*
          Leaves 1–2-pinnate; oil tubes numerous . . . . 24. *Berula.*
    D. Length of fruit greater than width.
      E. Leaves simple or 1–3-ternate.
        Oil tubes none; flowers white, 23. *Aegopodium.*
        Oil tubes present; flowers yellow.
          Oil tubes solitary in intervals and beneath ribs . . . . 17. *Zizia.*
          Oil tubes numerous . . . . 16. *Taenidia.*
      E. Leaves neither simple nor ternate.
        Leaves 1–2-pinnate; flowers white.
          Ribs of fruit inconspicuous . . 27. *Carum.*
          Ribs of fruit prominent, corky . . . . 25. *Sium.*
        Leaves finely dissected; flowers yellow . . . . 18. *Foeniculum.*
  C. Fruit not flattened laterally.
    D. Fruit not much flattened either way.
      E. Fruit ribs acutish; flowers white, 19. *Coriandrum.*
      E. Fruit ribs winged; flowers yellow . . 15. *Thaspium.*
    D. Fruit strongly flattened dorsally.

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examined from Berrien Co. (C. K. Dodge, 1917). Said to be an abundant weed in cornfields. Probably a survival from cultivation.

Carum copticum Benth. & Hk., Bishop's-Weed, is similar to *Carum carui*, but has an involucre of many bracts, an involucel of 3–5 bracts, and pubescent umbel rays. Reported by O. A. Farwell on ballast grounds at Detroit.

Torilis nodosa (L.) Gaertn., Knotted Hedge Parsley, may be recognized by its bipinnate leaves and ovoid fruits armed with hooked prickles. Reported by O. A. Farwell on ballast grounds at Detroit.

Pimpinella anisum L., Anise, is an annual herb with round-cordate undivided lower leaves, involucre and involucel of one linear bract each or none, and white flowers. Reported by O. A. Farwell on ballast grounds at Detroit.

E. Flowers yellow; style base depressed.
- Fruit margin thick, corky; ribs obscure .... 7. *Pleiotaenia.*
- Fruit margin thin; ribs distinct.
  - Involucre absent .... 8. *Pastinaca.*
  - Involucre present.......... 9. *Hipposelinum.*

E. Flowers white; style base mostly conical
- Oil tubes solitary in intervals between ribs
  - Oil tubes large, not extending to base of fruit......10. *Heracleum.*
  - Oil tubes slender, extending to base of fruit.
    - Leaves pinnate..........13. *Oxypolis.*
    - Leaves ternate..........14. *Imperatoria.*
- Oil tubes 2 → many in intervals.
  - Leaf segments very narrow..11. *Conioselinum.*
  - Leaf segments broad.......12. *Angelica.*

KEY BASED ON LEAF AND FLOWER CHARACTERS

A. Leaves wholly or in part simple.
- B. Leaves all simple.
  - Leaves orbicular..........................20. *Hydrocotyle.*
  - Leaves long-linear.......................... 1. *Eryngium.*
- B. Only basal leaves simple......................17. *Zizia cordata.*

A. Leaves not simple.
- B. Leaves pinnately compound.
  - C. Leaves all or partly once pinnate.
    - D. Flowers yellow........................ 8. *Pastinaca.*
    - D. Flowers white.
      - Lower leaves once pinnate.
        - Leaf segments entire or coarsely toothed........................13. *Oxypolis.*
        - Leaf segments sharply toothed or incised..........................24. *Berula.*
      - Lower leaves pinnately decompound...25. *Sium.*
  - C. Leaves 2 or more times pinnate.
    - D. Flowers yellow.
      - Calyx prominent.................... 7. *Pleiotaenia.*
      - Calyx none.........................18. *Foeniculum.*
    - D. Flowers white.
      - Purple flower in center of umbel...... 3. *Daucus.*
      - No purple flower.
        - Involucel none.....................27. *Carum.*
        - Involucel present.
          - Involucel bracts ovate...........22. *Conium.*

Involucel bracts linear.
Calyx absent . . . . 11. *Conioselinum.*
Calyx present.
Perennials, in swamps . . . . 26. *Cicuta.*
Annual, in waste places . . . . . . 19. *Coriandrum.*
B. Leaves palmately or ternately compound.
C. Leaves once palmate, of 3–5 leaflets.
Some staminate flowers present . . . . 2. *Sanicula.*
Flowers all perfect.
Flowers yellow or purple . . . . 15. *Thaspium.*
Flowers white.
Involucel none . . . . 6. *Deringa.*
Involucel of many linear bracts . . . . . . 10. *Heracleum.*
C. Leaves 2 or more times ternate.
D. Flowers yellow (sometimes purple in Thaspium).
Involucre present . . . . 9. *Hipposelinum.*
Involucre absent.
Involucel and calyx present.
Ribs of fruit not winged . . . . 17. *Zizia.*
Ribs of fruit winged . . . . 15. *Thaspium.*
Involucel and calyx absent . . . . 16. *Taenidia.*
D. Flowers white.
E. Umbel 2–6-rayed.
Involucre a compound leaf . . . . 21. *Erigenia.*
Involucre of small bracts or none.
Perennials; leaf segments broad, 4. *Washingtonia.*
Annuals; leaf segments narrow . . 5. *Chaerophyllum.*
E. Umbels more than 6-rayed.
Involucels absent . . . . 23. *Aegopodium.*
Involucels present.
Carpels with their lateral wings distinct . . . . 12. *Angelica.*
Carpels with their lateral wings united . . . . 14. *Imperatoria.*

1. Eryngium [Tourn.] L.

(Greek, a kind of thistle)

1. *Eryngium aquaticum* L. ('aquatic')
Eryngium yuccaefolium Michx.
Rattlesnake Master; Button Snakeroot.
A plant of the prairies, occurring only in the southwestern counties of Michigan.

Specimens examined. — Berrien Co. (George Ames, 1867); Van Buren Co. (H. S. Pepoon, 1903, 1905, reported as occasional

through the Magician Lake district); St. Joseph Co. (Dr. Wright, 1838; F. P. Daniels, 1898).

2. Sanicula L. Snakeroot

(From Latin *sanare*, 'to heal')

Styles much exceeding bristles of the fruit, recurved.
  Fruit 6–7 mm. long, sessile; calyx segments mostly lanceolate, cuspidate............................1. *S. marylandica.*
  Fruit 3–4 mm. long, somewhat stalked; calyx segments mostly ovate, obtuse......................2. *S. gregaria.*
Styles shorter than bristles of the fruit.
  Pedicels of staminate flowers 2 mm. long; fruit subglobose.......................................3. *S. canadensis.*
  Pedicels of staminate flowers 4 mm. long; fruit ovoid or fusiform.................................4. *S. trifoliata.*

1. *Sanicula marylandica* L. ('of Maryland')
Black Snakeroot; Sanicle.
All parts of state in woodlands, principally beech and oak.

Specimens examined. — Van Buren Co. (H. S. Pepoon, 1916); Washtenaw Co. (E. C. Allmendinger, 1870); Allegan Co. (H. M. Bailey, 1891); Eaton Co. (H. T. Darlington, 1916); Ingham Co. (C. F. Wheeler, 1901); Oakland Co. (C. Billington, 1914); Macomb Co. (D. Cooley, 1868); St. Clair Co. (C. K. Dodge, 1892); Genesee Co. (D. Clark); Ionia Co. (C. F. Wheeler); Newaygo, Osceola and Alcona counties (Bessey & Darlington, 1916–1918); Charlevoix Co. (E. A. Bessey, 1912); Cheboygan Co. (F. C. Gates, 1911); Alger Co. (C. K. Dodge, 1916); Ontonagon Co. (H. T. Darlington, 1922); Keweenaw Co. (F. E. Wood, 1883); Isle Royale (Univ. of Mich. party, 1868).

Reported from St. Joseph Co. (F. P. Daniels); Calhoun Co. (C. E. Barr); Wayne Co. (O. A. Farwell); Kent Co. (C. W. Fallass); Muskegon Co. (C. D. McLouth); Tuscola Co., Huron Co., Charity Islands, Bay Co. to Cheboygan Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); Emmet Co. (Fallass and Swift); Mackinac Island, Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons).

2. *Sanicula gregaria* Bicknell ('clustered')
   Clustered Snakeroot.
   Restricted mainly to southern part of state; mostly in woodlands.

Specimens examined. — Monroe Co. (C. Billington, 1918); Washtenaw Co. (B. A. Walpole, 1919); Van Buren Co. (H. S. Pepoon, 1908); Ingham Co. (C. F. Wheeler); St. Clair Co. (C. K. Dodge, 1911); Muskegon Co. (C. D. McLouth, 1899); Newaygo Co. (Bessey & Darlington, 1916).

Reported from Wayne Co. (O. A. Farwell); Kent Co. (Emma J. Cole); Gratiot Co. (C. A. Davis); Lake Co. (L. H. Harvey); Cheboygan Co. (F. C. Gates); Keweenaw Co. (O. A. Farwell).

3. *Sanicula canadensis* L. ('of Canada')
   Short-styled Snakeroot.
   Practically restricted to the southern counties in climax (beech-maple) forests.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Lenawee Co. (C. Billington, 1916); Washtenaw Co. B. A. Walpole, 1918); Wayne Co. (C. K. Dodge, 1911); Kent Co. (H. M. Bailey, 1892).

Reported from Van Buren Co. (H. S. Pepoon); Oakland Co. (J. W. Stacey); Genesee, Ionia and Gratiot counties (Beal's catalog); Emmet Co. (Fallass & Swift, "rare").

4. *Sanicula trifoliata* Bicknell ('three-leaved')
   Large-fruited Snakeroot.
   Woods, practically restricted to the southern counties.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1907); Cass Co. (A. B. Burgess, 1903); Van Buren Co. (H. S. Pepoon, 1906); Washtenaw Co. (B. A. Walpole, 1919); Ingham Co. (C. S. W., 1907); Muskegon Co. (C. D. McLouth, 1899); Gratiot Co. (C. F. Wheeler, 1890).

Reported from Oakland Co. (O. A. Farwell); Kent Co., Emmet Co. (C. W. Fallass).

3. Daucus (Tourn.) L.

(Greek name)

Daucus carota L. (Latin name)
Wild Carrot.
Naturalized from Europe. Fields and waste places.

Specimens examined. — Berrien Co. (J. M. Coulter, 1891); Cass Co. (H. S. Pepoon, 1905); Van Buren Co. (1911); Jackson Co. (S. H. & D. R. Camp, 1897); Wayne Co. (C. Billington, 1914); Washtenaw Co. (P. J. Podolski, 1917); Ingham Co. (L. A. Kenoyer, 1922); St. Clair Co. (C. K. Dodge, 1894); Oceana Co. (1911); Mason Co. (R. W. Chaney, 1910); Charlevoix Co. (J. H. Ehlers, 1917); Keweenaw Co. (O. A. Farwell, 1888).

Reported from St. Joseph Co. (F. P. Daniels); Allegan Co., Eaton Co. (M. A. C. determination); Oakland Co. (J. W. Stacey); Kent Co. (C. W. Fallass); Muskegon Co. (H. T. Darlington); Newaygo Co. (M. A. C. determination); Tuscola Co., Huron Co. (C. K. Dodge); Manistee Co. (F. P. Daniels); Wexford Co. (M. A. C. determination); Kalkaska Co. (E. A. Bessey); Alpena Co., Cheboygan Co. (C. K. Dodge); Emmet Co. (Fallass & Swift); Schoolcraft Co. (C. K. Dodge).

4. Washingtonia Raf. Sweet Cicely

(in honor of George Washington)

Involucels of several persistent bracts.
  Style foot and style 1 mm. long or less................1. *W. claytoni.*
  Style foot and style 2–4 mm. long.........................2. *W. longistylis*
Involucels none.
  Fruit beaked, on ascending pedicels; style foot conic..3. *W. divaricata.*
  Fruit blunt, on divergent pedicels; style foot depressed, 4. *W. obtusa.*

1. *Washingtonia claytoni* (Michx.) Britton. ('Clayton's')
Osmorhiza claytoni (Michx.) Clarke.
Hairy Sweet Cicely; Sweet Javril.
All over state in climax (beech-maple) forests.

Specimens examined. — Monroe Co. (O. A. Farwell, 1920); Van Buren Co. (H. S. Pepoon, 1906); Jackson Co. (S. H. &

D. R. Camp, 1897); Washtenaw Co. (Lewis Foote, 1863); Wayne Co. (C. Billington, 1914); Ingham Co. (B. A. Walpole, 1922); Eaton Co. (H. T. Darlington, 1916); Macomb Co. (D. Cooley, 1841); St. Clair Co. (C. K. Dodge, 1892); Kent Co. (H. M. Bailey, 1892); Muskegon Co. (C. D. McLouth, 1899); Ogemaw Co. (W. G. Winslow, 1912); Emmet Co. (F. C. Gates, 1917); Cheboygan Co. (F. C. Gates, 1911); Marquette Co. (B. Barlow, 1901); Gogebic Co. (H. T. Darlington, 1922); Keweenaw Co. (O. A. Farwell, 1887).

Reported from Calhoun Co. (C. E. Barr); Oakland Co. (J. W. Stacey); Gratiot Co. (C. A. Davis); Mecosta Co. (C. W. Fallass); Huron Co., Tuscola Co., Bay Co. to Cheboygan Co. along coast (C. K. Dodge); Charlevoix Co. (E. A. Bessey); Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons).

2. *Washingtonia longistylis* (Torr.) Britton. ('long-styled')
Osmorhiza longistylis (Torr.) DC.
Smoother Sweet Cicely; Anise Root.
Distributed all over state in climax (beech-maple) forests. All examined specimens come from the southeastern counties.

Specimens examined. — Wayne Co. (C. Billington, (1914) Washtenaw Co. (Lewis Foote, 1863); Ingham Co. (1865); Oakland Co. (C. Billington, 1917); Macomb Co. (D. Cooley, 1841); St. Clair Co. (C. K. Dodge, 1892); Missaukee Co. (C. Billington, 1917).

Reported from Magician Lake district (H. S. Pepoon); St. Joseph Co. (F. P. Daniels); Kent Co. (Emma J. Cole); Gratiot Co. (C. A. Davis); Mecosta Co. (C. W. Fallass); Huron Co., Charity Islands, Tuscola Co., Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); Charlevoix Co. (C. W. Fallass); Emmet Co. (Fallass & Swift); Cheboygan Co. (F. C. Gates); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Gogebic Co. (H. T. Darlington).

Var. *villicaulis* is reported from Schoolcraft Co. by C. K. Dodge.

3. *Washingtonia divaricata* Britton. ('spreading')
Osmorhiza divaricata Nutt.
Western Sweet Cicely.
Hardwood forests. Distribution limited, in the northern part of the state.

Specimens examined. — Alpena Co. (C. K. Dodge, 1907); Mackinac Is. (C. F. Millspaugh, 1898); Chippewa Co. (C. K. Dodge, 1914); Alger Co. (K. K. Mackenzie); Isle Royale (U. of Mich. party, 1868).

Reported from Emmet Co. (Fallass & Swift); Mackinac Co. (C. K. Dodge); Schoolcraft Co. (C. K. Dodge).

4. *Washingtonia obtusa* Coult & Rose. ('obtuse')
Osmorhiza obtusa (Coult. & Rose) Fernald.
Blunt-fruited Sweet Cicely.

Reported from Gogebic Co. (H. T. Darlington, 1920).

Specimens from Isle Royale, probably *W. divaricata*, collected by Dr. A. E. Foote, seem to approach this species in the shortness of the style and the beak.

5. Chaerophyllum [Tourn.] L.

(Greek, 'pleasant leaf')

Chaerophyllum procumbens (1.) Crantz. ('procumbent')
Spreading Chervil.
Moist or shaded ground. Limited to the southern part of the state.

Specimens examined. — Monroe Co. (C. F. Wheeler, 1890, C. Billington, 1914); Ingham Co. (1865); Kent Co. (Emma J. Cole, 1895).

Reported from Berrien Co. (C. Billington, "plentiful"); Kalamazoo Co. (Frank H. Tuthill); Macomb Co. (C. & S.).

6. Deringa Adans.

Deringa canadensis (L.) Kuntze. ('of Canada')
Cryptotaenia canadensis (L.) DC.
Honewort.
Climax (beech-maple) woods, mainly in the southern portion.

Specimens examined. — Berrien Co. (F. W. Johnson, 1914); Cass Co. (H. S. Pepoon, 1903); Kalamazoo Co. (A. B. Burgess, 1903); Calhoun Co. (W. J. Beal, 1898); Jackson Co. (S. H. & D. R. Camp, 1898); Washtenaw Co. (E. C. Allmendinger); Wayne Co. (C. Billington, 1914); Macomb Co. (D. Cooley, 1841); Ingham Co. (H. T. Darlington, 1916); Eaton Co. (H. T. Darlington, 1916); Kent Co. (H. M. Bailey, 1892); Ionia Co. (C. F. Wheeler, 1890); St. Clair Co. (C. K. Dodge, 1892); Osceola Co. (Bessey & Darlington, 1916).

Reported from Oakland Co. (J. W. Stacey); Muskegon Co. (C. D. McLouth); Tuscola Co., Huron Co. (C. K. Dodge); Manistee Co. (F. P. Daniels); Dickinson Co. (G. H. Coons); Marquette Co. (A. Dachnowski).

7. Pleiotaenia Coult. & Rose.

(Greek, 'many oil tubes')

Pleiotaenia nuttallii (DC.) Coult. & Rose. ('Nuttall's')
Polytaenia nuttallii DC.
Prairie Parsley.
A prairie plant with range southward and westward, reported from southern Michigan by Beal's catalog, Gray's *Manual* and Britton & Brown's *Illustrated Flora.* No definite locality reports found.

8. Pastinaca L.

(Latin, *pastus*, 'food')

Pastinaca sativa L. ('sown')
Wild Parsnip.
Naturalized from Europe.

Specimens examined. — Washtenaw Co. (E. C. Allmendinger, 1880); Oakland Co. (C. Billington, 1914); Ingham Co. (1871); Muskegon Co. (C. D. McLouth, 1899); Kent Co. (H. M. Bailey, 1892); St. Clair Co. (C. K. Dodge, 1892); Cheboygan Co. (F. C. Gates, 1911); Emmet Co. (J. H. Ehlers, 1920); Mackinac Is. (C. F. Millspaugh, 1898); Marquette Co. (B. Barlow, 1901).

Reported from Magician Lake district (H. S. Pepoon); St. Joseph Co. (F. P. Daniels); Wayne Co. (O. A. Farwell); Tuscola Co., Huron Co. (C. K. Dodge); Manistee Co. (F. P. Daniels); Mackinac Island, Schoolcraft Co. (C. K. Dodge); Isle Royale (W. S. Cooper).

9. Hipposelinum (Dalerech) Britton & Rose.

(Greek, 'horse-parsley')

Hipposelinum levisticum (L.) Britton & Rose

Levisticum officinale (L.) Koch.

Lovage.

Sparingly introduced from southern Europe.

Specimen examined. — Macomb Co. (D. Cooley, 1843).

Reported from Houghton Co. (O. A. Farwell).

10. Heracleum (L.)

(Greek, 'dedicated to Hercules')

Heracleum lanatum Michx. ('woolly')

Cow Parsnip.

Rather general in low areas, clearings, etc.

Specimens examined. — Jackson Co. (S. H. & D. R. Camp, 1897); Washtenaw Co. (B. A. Walpole, 1919); Ingham Co. (1865); Oakland Co. (C. Billington, 1914); Macomb Co. (D. Cooley, 1838); St. Clair Co. (C. K. Dodge. 1892); Kent Co. (H. M. Bailey, 1892); Muskegon Co. (C. D. McLouth, 1901); Mackinac Co. (J. H. Ehlers, 1917); Alger Co. (J. G. Coulter, 1892); Marquette Co. (B. Barlow, 1901); Keweenaw Co. (O. A. Farwell, 1888).

Reported from Cass Co. (H. S. Pepoon); Lenawee Co. (C. Billington); Calhoun Co. (C. E. Barr); Gratiot Co. (M. A. C. determination); Huron Co., Tuscola Co., Bay Co. to Mackinac Co. along coast, Mackinac Island (C. K. Dodge); Mason Co. (H. T. Darlington); Cheboygan Co. (F. C. Gates); Emmet Co. (Fallass & Swift); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Gogebic Co., Ontonagon Co. (H. T. Darlington); Isle Royale (W. S. Cooper).

11. Conioselinum Hoffm.

(Greek, 'hemlock-parsley')

Conioselinum chinense (L.) B. S. P. ('of China')
Hemlock Parsley.

Infrequent in swamps in the southern counties.

Specimens examined. — Cass Co. (H. S. Pepoon, 1906); Washtenaw Co. (A. J. Pieters, 1893); Oakland Co. (C. Billington, 1914); Macomb Co. (D. Cooley, 1844).

Reported from Ingham Co. (C. F. Wheeler); Kent Co. (Emma J. Cole); Ionia Co. (C. F. Wheeler); Genesee Co. (Beal's catalog).

12. Angelica L.

(Named 'angelic,' from its healing properties)

Umbels glabrous; seed becoming loose from pericarp...1. *A. atropurpurea*
Umbels densely tomentose; seed adhering to pericarp..2. *A. villosa.*

1. *Angelica atropurpurea* L. ('dark purple')
Purple-stemmed Angelica.

Rather infrequent in damp open ground, mainly in the southern counties.

Specimens examined. — Berrien Co. (G. D. Ames); Van Buren Co. (H. L. Pepoon, 1906); Monroe Co. (C. Billington, 1919); Washtenaw Co. (C. D. La Rue, 1915); Eaton Co. (L. J. Cole, 1895); Ingham Co. (H. T. Darlington, 1916); Macomb Co. (D. Cooley, 1837); St. Clair Co. (C. K. Dodge, 1896); Kent Co. (H. M. Bailey, 1892).

Reported from Hillsdale Co. (A. E. Camp); Calhoun Co. (C. E. Barr); Gratiot Co. (C. A. Davis); Huron Co., Bay Co., Arenac Co. (C. K. Dodge); Emmet Co. (Fallass & Swift); Schoolcraft Co. (C. K. Dodge).

2. *Angelica villosa* (Walt.) B. S. P. ('rough hairy')
Hairy Angelica.
Practically confined to the three southern tiers of counties.

Specimens examined. — Lenawee Co. (W. J. Beal, 1866); Kalamazoo Co. (collector unknown); Calhoun Co. (W. J. Beal, 1898); Washtenaw Co. (C. D. La Rue, 1915); Wayne Co. (C. Billington, 1914); Ingham Co. (1865); Oakland Co. (D. Clark, 1880).

Reported from Emmet Co. (Winchell's catalog).

13. Oxypolis Raf.

Oxypolis rigidius (L.) Raf. ('more rigid')
Oxypolis rigidior (L.) Coult. & Rose.
Cowbane, Hemlock, Water Dropwort.
Swamps, in the southern counties.

Specimens examined. — Berrien Co. (G. L. Ames, 1867); Cass Co. (H. S. Pepoon, 1904); Jackson Co. (G. H. Hicks, 1893); Washtenaw Co. (B. A. Walpole, 1918); Oakland Co. (C. Billington, 1914); Allegan Co. (W. A. Dahmen, 1898); Ionia Co. (C. F. Wheeler, 1890); Kent Co. (G. D. Sones, 1891); Montcalm Co. (B. Barlow, 1900).

Reported from Calhoun Co. (C. E. Barr); Cheboygan Co. (F. C. Gates).

14. Imperatoria [Tourn.] L.

(Latin, *imperator*, 'emperor,' in allusion to its powerful medicinal qualities)

Imperatoria ostruthium L. ('ostrich')
Masterwort; Pellitory of Spain.
Sparingly introduced from Europe.

Reported from Ionia Co. (DeVore); Muskegon Co. (C. D. McLouth).

15. Thaspium Nutt. Meadow Parsnip.

(Named from the island Thapsus)

Leaf segments serrate or crenate........................1. *T. trifoliatum.*
Leaf segments incised......................................2. *T. barbinode.*

1. *Thaspium trifoliatum* (L.) Britton. ('three-leaved')
Thaspium aureum Nutt.
Meadow Parsnip
Only south of Saginaw Bay. The Michigan specimens of this variable species are all yellow-flowered. There appear to be two distinct types, one, which will be designated *a*, with entire root leaves and ternate stem leaves, the other, *b*, with ternate root leaves and biternate stem leaves.

Specimens examined. — Cass Co. (*a*, C. F. Wheeler, 1890); St. Joseph Co. (*b*, A. B. Burgess, 1903); Monroe Co. (*b*, C. Billington, 1914); Wayne Co. (*a*, O. A. Farwell, 1893, C. F. Wheeler, 1893); Washtenaw Co. (*a*, J. H. Ehlers, 1918); Kalamazoo Co. (*a*, collector unknown); Oakland Co. (*b*, C. Billington, 1915); Genesee Co. (*a*, D. Clark); Kent Co. (*b*, H. M. Bailey, 1891).

Reported from Washtenaw Co. (*b*, O. A. Farwell); Tuscola Co. (C. A. Davis).

2. *Thaspium barbinode* (Michx.) Nutt. ('hairy-jointed')
Hairy-jointed Meadow Parsnip.
Of rare occurrence, in the three southern tiers of counties only.

Specimens examined. — Berrien Co. (E. J. Hill, 1895); Lenawee Co. (C. Billington, 1917); Jackson Co. (S. H. Camp, 1893, C. K. Dodge, 1893); Washtenaw Co. (J. L. Romein, 1915).

Reported from Calhoun Co. (C. E. Barr); Oakland Co. (J. W. Stacey).

16. Taenidia Drude.

(Greek, 'a little band,' in reference to the slender ribs)

Taenidia integerrima (L.) Drude. ('most entire')
Yellow Pimpernel.

Restricted to the Lower Peninsula, in woods and sand dunes.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Monroe Co. (C. F. Wheeler, 1890); Washtenaw Co. (J. P. Romein, 1915); Jackson Co. (S. H. & D. R. Camp, 1896); Calhoun Co. (W. J. Beal, 1898); Van Buren Co. (H. S. Pepoon, 1903); Ingham Co. (1865, 1887); Oakland Co. (C. Billington, 1914); Macomb Co. (D. Cooley, 1837); St. Clair Co. (C. K. Dodge, 1896); Shiawassee Co. (G. H. Hicks, 1889); Ionia Co. (C. F. Wheeler, 1890); Kent Co. (H. M. Bailey, 1892); Muskegon Co. (C. D. McLouth, 1899); Clare Co. (1888); Arenac Co. (C. F. Wheeler, 1900); Roscommon Co. (Bessey & Darlington, 1916); Alcona Co. (Bessey & Darlington, 1918); Cheboygan Co. (J. H. Ehlers, 1921); Emmet Co. (J. H. Ehlers, 1917).

Reported from St. Joseph Co. (F. P. Daniels); Wayne Co. (O. A. Farwell); Gratiot Co. (C. A. Davis); Mecosta Co. (C. W. Fallass); Huron Co., Tuscola Co., Bay Co. to Cheboygan Co. along coast, Mackinac Island (C. K. Dodge); Manistee Co. (F. P. Daniels).

17. Zizia Koch.

(Named for I. B. Ziz, a Rhenish botanist)

Basal leaves cordate . . . . 1. *Z. cordata.*
Basal leaves 2–3-ternate . . . . 2. *Z. aurea.*

1. *Zizia cordata* (Walt.) DC. ('heart-shaped')
Heart-leaved Alexanders.

Reported from Cass Co. (C. F. Wheeler); Kent Co. (Emma J. Cole); and Genesee Co. (Beal's catalog). No specimens seen. There is a probability that plants referred to this

species really belong to *Thaspium trifoliatum*, which the writer has seen from all three of the counties mentioned.

2. *Zizia aurea* (L.) Koch. ('golden')
Golden Alexanders; Early Meadow Parsnip.
Meadows and open swamps, only south of Saginaw Bay. This species has a superficial resemblance to the biternate form of *Thaspium trifoliatum*, but it may be distinguished by the absence of wings on the fruit and by the sessile fruit in the center of each umbellet.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Cass Co. (H. S. Pepoon, 1906); Kalamazoo Co. (R. M. Gibbs, 1877); Jackson Co. (W. & L., 1898); Washtenaw Co. (B. A. Walpole, 1918); Wayne Co. (K. K. Mackenzie, 1911); St. Clair Co. (C. K. Dodge, 1896); Genesee Co. (D. Clarke); Ionia Co. (C. F. Wheeler, 1890); Muskegon Co. (C. D. McLouth, 1901); Keweenaw Co. (O. A. Farwell, 1889).

Reported from St. Joseph Co. (F. P. Daniels); Calhoun Co. (C. E. Barr); Oakland Co. (O. A. Farwell); Kent Co. (Emma J. Cole); Tuscola Co., Huron Co. (C. K. Dodge).

18. Foeniculum Mill.

(Latin diminutive of *foenum*, 'hay,' from its odor)

Foeniculum foeniculum (L.) Karst.
Foeniculum vulgare Hill.
Fennel.
Sparingly introduced from Europe.

Specimens examined. — Wayne Co. (C. Billington, 1916); Washtenaw Co. (W. M. Canby, 1862); Ingham Co. (W. J. Beal, 1900); Eaton Co. (H. T. Darlington, 1916); Mason Co. (Miss Maule, 1915).

Reported from Kent Co. (Emma J. Cole); Manistee Co. (F. P. Daniels).

19. Coriandrum [Tourn.] L.

(Ancient Latin name.)

Coriandrum sativum L. ('sown')
Coriander.
An escape from cultivation. Eurasia.
Reported from Wayne Co. (O. A. Farwell, streets of Detroit).

20. Hydrocotyle L.

(Greek, 'water cup')

Leaves peltate; umbels many-flowered .... 1. *H. umbellata.*
Leaves reniform; umbels 1–5-flowered .... 2. *H. americana.*

1. *Hydrocotyle umbellata L.* ('in umbels')
Umbellate Water Pennywort.
Ponds and marshes; almost restricted to the area south of Saginaw Bay.
Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Cass Co. (F. C. Gates, 1906); Van Buren Co. (H. S. Pepoon, 1903); Kalamazoo Co. (1838); Calhoun Co. (W. J. Beal, 1898); Washtenaw Co. (B. A. Walpole, 1920); Ingham Co. (1887); Allegan Co. (O. A. Farwell, 1920); Genesee Co. (D. Clarke).
Reported from Kent Co. (Emma J. Cole); Ionia Co., Gratiot Co. (Beal's catalog); Cheboygan Co. (McFarland).

2. *Hydrocotyle americana* L. ('American')
American Water Pennywort.
Ponds and swamps, mostly in the Lower Peninsula.
Specimens examined. — Washtenaw Co. (B. A. Walpole, 1920); Oakland Co. (C. Billington, 1914); Eaton Co. (H. T. Darlington, 1916); Osceola Co. (Bessey & Darlington, 1916); Chippewa Co. (Lewis Foote, 1867).
Reported from Kent Co. (C. W. Fallass); Gratiot Co., Huron Co. (C. A. Davis); Manistee Co. (F. P. Daniels); Emmet Co. (Fallass & Swift).

21. Erigenia Nutt.

(Greek, 'spring-born')

Erigenia bulbosa (Michx.) Nutt. ('bulb-bearing')
Harbinger of Spring.

In low woods in the counties south of Saginaw Bay. One of the earliest plants to bloom in spring.

Specimens examined. — Cass Co. (H. S. Pepoon, 1906); Van Buren Co. (H. S. Pepoon, 1906); Jackson Co. (S. H. & D. R. Camp, 1897); Washtenaw Co. (E. C. Allmendinger, 1871); Wayne Co. (S. M. Keenan, 1914); Macomb Co. (D. Cooley, 1850); Oakland Co. (B. F. Chandler, 1916); Ingham Co. (F. L. Sleeper, 1867); Kent Co. (H. M. Bailey, 1893); Genesee Co. (D. Clarke); Gratiot Co. (C. A. Davis, 1890); St. Clair Co. (C. K. Dodge, 1893).

Reported from Berrien Co. (C. Billington); Calhoun Co. (C. E. Barr); Eaton Co. (Shoop).

22. Conium L.

(Greek, 'hemlock')

Conium maculatum L. ('spotted')
Poison Hemlock. Snakeweed.

Naturalized from Europe; in waste places.

Specimens examined. — Jackson Co. (S. H. Camp, 1894); Oakland Co. (B. F. Chandler, 1915); Macomb Co. (D. Cooley, 1844); St. Clair Co. (C. K. Dodge, 1898); Ionia Co. (C. F. Wheeler, 1890); Leelanau Co. (H. M. Bailey, 1891); Emmet Co. (C. F. Wheeler, 1890); Mackinac Is. (C. F. Millspaugh, 1898).

Reported from St. Joseph Co. (M. A. C. determination); Wayne Co. (O. A. Farwell); Ingham Co. (B. A. Walpole); Kent Co. (Emma J. Cole); Tuscola Co., Mackinac Co., Mackinac Island, Schoolcraft Co. (C. K. Dodge).

23. Aegopodium L.

(Greek, 'goat foot')

Aegopodium podagraria L. ('for the gout')
Goutweed; Goutwort; Herb Gerard.

Sparingly introduced from Europe.

Specimens examined. — Ingham Co. (1887); St. Clair Co. (C. K. Dodge, "a permanent escape").

24. Berula Hoffm.

(Latin name of water cress)

Berula erecta (Huds.) Coville. ('erect')
Cut-leaved Water Parsnip.

Swamps, mainly restricted to the southeastern counties.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Cass Co. (H. S. Pepoon, 1904).

Reported from Kalamazoo Co. (F. H. Tuthill); Oakland Co. (F. P. Daniels); Manistee Co. (J. W. Stacey).

25. Sium [Tourn.] L.

(Greek name of a marsh plant)

Sium cicutaefolium Schrank. ('Cicuta-leaved')
Hemlock Water Parsnip.

All parts of the state, in water or swampy places.

Specimens examined. — Monroe Co. (B. A. Walpole, 1920); Wayne Co. (C. Billington, 1915); Washtenaw Co. (E. C. Allmendinger, 1870); Eaton Co. (H. T. Darlington, 1916); Kent Co. (G. D. Sones, 1901); St. Clair Co. (C. K. Dodge, 1892); Cheboygan Co. (F. C. Gates, 1911); Alger Co. (C. F. Wheeler, 1900); Marquette Co. (B. Barlow, 1901); Gogebic Co. (H. T. Darlington, 1919); Ontonagon Co. (H. T. Darlington, 1922); Keweenaw Co. (F. E. Wood, 1888); Isle Royale (U. of Mich. party, 1868).

Reported from Magician Lake district (H. S. Pepoon); Ingham Co. (C. F. Wheeler); Oakland Co. (J. W. Stacey);

Clinton Co. (Beal's catalog); Muskegon Co. (C. D. McLouth); Gratiot Co. (M. A. C. identification); Huron Co., Tuscola Co., Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); Emmet Co. (Fallass & Swift); Beaver Island (H. T. Darlington); Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons).

26. Cicuta L. Water Hemlock.

(Ancient Latin name)

Leaf segments lanceolate . . . . 1. *C. maculata.*
Leaf segments narrowly linear . . . . 2. *C. bulbifera.*

1. *Cicuta maculata* L. ('spotted')
Water or Spotted Hemlock; Musquash Root.
Swamps and marshes, particularly in southern and southeastern counties.

Specimens examined. — Lenawee Co. (W. J. Beal, 1866); Cass Co. (A. B. Burgess, 1903); Van Buren Co. (H. S. Pepoon, 1905); Kalamazoo Co. (A. B. Burgess, 1903); Calhoun Co. (W. J. Beal, 1898); Jackson Co. (S. H. & D. R. Camp, 1896); Washtenaw Co. (B. A. Walpole, 1918); Wayne Co. (Lewis Foote, 1870); Oakland Co. (C. Billington, 1916); Ingham Co. (1871); Shiawassee Co. (G. H. Hicks, 1889); St. Clair Co. (C. K. Dodge, 1892); Muskegon Co. (C. D. McLouth, 1892); Mackinac Is. (C. F. Millspaugh, 1898).

Reported from Monroe Co., Livingston Co., Lapeer Co. (M. A. C. identification); Genesee Co. (E. A. Bessey); Kent Co. (C. W. Fallass); Ottawa Co. (E. A. Bessey); Saginaw Co. (M. A. C. identification); Huron Co., Charity Islands, Tuscola Co., Bay Co. to Cheboygan Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); Emmet Co. (Fallass & Swift); Dickinson Co. (G. H. Coons); Gogebic Co. (H. T. Darlington).

2. *Cicuta bulbifera* L. ('bulb-bearing')
Bulb-bearing Water Hemlock.
Swamps and marshes all over the state. Apparently least frequent in the jack-pine region.

Specimens examined. — Lenawee Co. (H. H. Winchell, 1862); Washtenaw Co. (B. A. Walpole, 1918); Jackson Co. (S. H. & D. R. Camp, 1898); Van Buren Co. (H. S. Pepoon, 1905); Eaton Co. (H. T. Darlington, 1916); Ingham Co. (1887); St. Clair Co. (C. K. Dodge, 1896); Ionia Co. (C. F. Wheeler, 1889); Kent Co. (B. E. Livingstone, 1895); Montcalm Co. (B. Barlow, 1900); Mason Co. (R. W. Chaney, 1910); Crawford Co. (G. H. Hicks, 1888); Cheboygan Co. (J. H. Ehlers, 1921); Chippewa Co. (J. H. Ehlers, 1920); Marquette Co. (B. Barlow, 1901); Gogebic Co. (H. T. Darlington, 1919); Ontonagon Co. (Lewis Foote, 1865); Keweenaw Co. (O. A. Farwell, 1886).

Reported from St. Joseph Co. (F. P. Daniels); Calhoun Co. (C. E. Barr); Wayne Co. (O. A. Farwell); Oakland Co. (J. W. Stacey); Muskegon Co. (C. D. McLouth); Huron Co., Charity Islands, Tuscola Co., Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); North Manitou Island (E. N. Transeau); Emmet Co. (Fallass & Swift); Beaver Island (H. T. Darlington); Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons); Isle Royale (W. S. Cooper).

27. Carum L.

(Greek name)

Carum carui L.

Caraway.

Naturalized from Europe, chiefly about cities and along roads.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Washtenaw Co. (B. A. Walpole, 1918); Wayne Co. (C. Billington, 1916); Genesee Co. (D. Clarke); St. Clair Co. (C. K. Dodge, 1892); Alpena Co. (Bessey & Darlington, 1918); Keweenaw Co. (O. A. Farwell, 1898).

Reported from Calhoun Co. (C. E. Barr); Kent Co. (C. W. Fallass); Huron Co., Tuscola Co., Bay Co. to Cheboygan Co., Mackinac Island (C. K. Dodge); Manistee Co. (F. P. Daniels); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Gogebic Co. (H. T. Darlington).

III. *CORNACEAE* (Dogwood Family)

Flowers perfect, 4-merous; ovary 2-locular.
  Flowers in cymes, without involucre ....1. *Cornus.*
  Flowers in heads, with involucre.
    Trees or large shrubs ....2. *Cynoxylon.*
    Small undershrubs ....3. *Chamaepericlymenum.*
Flowers dioeciously polygamous, 5-merous; ovary
  1-locular ....4. *Nyssa.*

1. Cornus [Tourn.] L. Dogwood

(Latin, 'horn,' from the hardness of the wood)

Leaves alternate ....1. *C. alternifolia.*
Leaves opposite.
  Pubescence woolly and spreading.
    Leaves broadly ovate or orbicular ....2. *C. rugosa.*
    Leaves ovate or ovate-lanceolate.
      Fruit blue; leaves often rusty beneath ....3. *C. amomum.*
      Fruit white; leaves not rusty.
        Leaves scabrous above ....4. *C. asperifolia.*
        Leaves not scabrous ....5. *C. baileyi.*
  Pubescence closely appressed.
    Leaves ovate, short-pointed ....6. *C. stolonifera.*
    Leaves lanceolate, acuminate ....7. *C. femina.*

1. *Cornus alternifolia* L. f. ('alternate-leaved')
   Alternate-leaved Cornel or Dogwood.
   All over the state in woods and on stream banks.

Specimens examined. — Berrien Co. (C. F. Wheeler, 1890); Cass Co. (H. S. Pepoon, 1903); Kalamazoo Co. (R. M. Gibbs, 1877); Calhoun Co. (collector unknown); Washtenaw Co. (Matheson, 1910); Oakland Co. (C. Billington, 1914); Ingham Co. (1872); Kent Co. (P. Stein, 1891); St. Clair Co. (C. K. Dodge, 1896); Gratiot Co. (C. A. Davis, 1889); Montcalm Co. (B. O. Longier, 1900); Newaygo Co. (E. A. Bessey, 1916); Osceola Co. (E. A. Bessey, 1916); Roscommon Co. (Bessey & Darlington, 1916); Charlevoix Co. (E. A. Bessey, 1912); Emmet Co. (F. C. Gates, 1917); Cheboygan Co. (J. H. Ehlers, 1917); Alger Co. (C. F. Wheeler, 1900); Baraga Co. (H. T. Darlington,

1920); Gogebic Co. (Bessey & Darlington, 1919); Ontonagon Co. (H. T. Darlington); Keweenaw Co. (O. A. Farwell, 1886).

Reported from Huron Co. (C. A. Davis); Charity Islands, Tuscola Co., Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Dickinson Co., Houghton Co. (E. A. Bessey).

2. *Cornus rugosa* Lam. ('wrinkled')
Cornus circinata L'Her.
Round-leaved Cornel or Dogwood.
All over the state, mostly in open woods or sandy places.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Cass Co. (H. S. Pepoon, "very rare"); Jackson Co. (G. H. Hicks, 1893); Washtenaw Co. (C. D. La Rue, 1915); Oakland Co. (C. Billington, 1917); Macomb Co. (D. Cooley); St. Clair Co. (C. K. Dodge, 1892); Ionia Co. (C. F. Wheeler, 1889); Montcalm Co. (C. F. Wheeler, 1900); Muskegon Co. (C. D. McLouth, 1900); Grand Traverse Co. (C. F. Wheeler, 1898); Leelanau Co. (Pearl McCoy, 1917); Alpena Co. (C. F. Wheeler, 1895); Cheboygan Co. (F. C. Gates, 1911); Mackinac Co. (B. F. Chandler, 1914); Marquette Co. (A. Dachnowski, 1906); Ontonagon Co. (H. T. Darlington, 1922); Keweenaw Co. (F. E. Wood, 1883); Isle Royale (A. E. Foote, 1868).

Reported from St. Joseph Co. (W. J. Beal); Kent Co. (Emma J. Cole, "rare"); Gratiot Co., Huron Co. (C. A. Davis); Charity Islands, Tuscola Co., Bay Co. to Mackinac Co. along coast, Mackinac Island (C. K. Dodge); Manistee Co. (F. P. Daniels); Emmet Co. (Fallass & Swift); Beaver Island (H. T. Darlington); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons).

3. *Cornus amomum* Mill. ('cinnamon')
Silky Cornel; Kinnikinnik.
All over the state except in the extreme northwest. Swampy places, streams and sand dunes.

Specimens examined. — Cass Co. (H. S. Pepoon, 1903); Van Buren Co. (H. S. Pepoon, 1904); Washtenaw Co. (E. C. Allmendinger); Wayne Co. (C. Billington, 1914); Macomb Co. (D. Cooley, 1839); Oakland Co. (C. Billington, 1916); Ingham Co. (A. N. D., 1871); Kent Co. (H. M. Bailey, 1892); St. Clair Co. (C. K. Dodge, 1896); Gratiot Co. (C. A. Davis, 1890); Muskegon Co. (W. J. Beal, 1898); Mecosta Co. (E. A. Bessey, 1916); Osceola Co. (H. T. Darlington, 1916); Cheboygan Co. (J. H. Ehlers, 1916); Marquette Co. (C. K. Dodge, 1916); Keweenaw Co. (O. A. Farwell, 1888).

Reported from St. Joseph Co. (F. P. Daniels); Calhoun Co. (C. E. Barr, 1908); Livingston Co. (E. A. Bessey); Ionia Co. (M. A. C. identification); Huron Co., Charity Islands, Tuscola Co., Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); Emmet Co. (Fallass & Swift); Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons).

4. *Cornus asperifolia* Michx. ('rough-leaved')
Rough-leaved Cornel or Dogwood.
Mostly restricted to the southeastern corner of the state.

Specimens examined. — Lenawee Co. (C. Billington, 1916); Monroe Co. (C. Billington, 1918); Wayne Co. (O. A. Farwell, 1892).

Reported from Calhoun Co. (C. F. Wheeler); Manistee Co. (F. P. Daniels).

5. *Cornus baileyi* Coult & Evans. ('Bailey's')
Bailey's Cornel or Dogwood.
Somewhat scattering over entire state; swamps and sand dunes. Said to grade into *C. stolonifera*.

Specimens examined. — Berrien Co. (C. F. Wheeler, 1890); Ottawa Co. (E. B. U., 1891); Ionia Co. (C. F. Wheeler, 1890); Muskegon Co. (L. M. Umbach, 1898); Huron Co. (C. A. Davis, 1896); Grand Traverse Co. (C. F. Wheeler, 1898); Alpena Co. (C. F. Wheeler, 1895); Cheboygan Co. (J. H. Ehlers, 1917); Emmet Co. (C. F. Wheeler, 1892); Mackinac Co., Mackinac Island (C. K. Dodge, 1912); Schoolcraft Co.

(C. A. Davis, 1905); Alger Co. (J. G. Coulter, 1892); Menominee Co. (J. H. Schuette, 1892); Keweenaw Co. (F. E. Wood, 1883).

Reported from Wayne Co. (John M. Sutton); Tuscola Co. (C. A. Davis); Bay Co. to Mackinac Co. along coast (C. K. Dodge, "frequent"); Manistee Co. (F. P. Daniels); Benzie Co., Beaver Island (H. C. Cowles); Gogebic Co. (H. T. Darlington).

6. *Cornus stolonifera* Michx. ('stolon-bearing')

Red-osier Cornel or Dogwood.

Sand dunes and bogs over entire state.

Specimens examined. — Cass Co. (H. S. Pepoon, 1905); St. Joseph Co. (C. F. Wheeler, 1890); Hillsdale Co. (D. A. Pelton, 1885); Washtenaw Co. (L. Foote, 1863); Ingham Co. (L. H. Cole, 1895); Oakland Co. (D. A. Pelton, 1885); Macomb Co. (D. Cooley, 1820); St. Clair Co. (C. K. Dodge, 1892); Ionia Co. (C. F. Wheeler, 1890); Gratiot Co. (C. A. Davis, 1891); Tuscola Co. (A. J. Pieters, 1914); Huron Co. (C. K. Dodge, 1909); Iosco Co. (J. M. Waterbury, 1915); Alpena Co. (C. F. Wheeler, 1895); Cheboygan Co. (F. C. Gates, 1911); Mackinac Co. (J. H. Ehlers, 1920); Alger Co. (C. F. Wheeler, 1900); Marquette Co. (B. Barlow, 1901); Gogebic Co. (E. A. Bessey, 1919); Keweenaw Co. (O. A. Farwell, 1888); Isle Royale, A. E. Foote, 1868).

Reported from Calhoun Co. (C. E. Barr); Wayne Co. (John M. Sutton); Allegan Co. (E. A. Bessey); Kent Co. (Emma J. Cole); Midland Co. (M. A. C. identification); Charity Islands, Bay Co. to Mackinac Co. along coast, Mackinac Island (C. K. Dodge); Manistee Co. (F. P. Daniels); Benzie Co. (H. C. Cowles); Leelanau Co. (S. M. Coulter); Charlevoix Co. (E. A. Bessey); Emmet Co. (Fallass & Swift); Beaver Island (H. C. Cowles); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons); Ontonagon Co. (H. T. Darlington).

7. *Cornus femina* Mill. ('woman')
   Panicled Cornel or Dogwood.
   Lower Peninsula, particularly southern part. Streams and thickets.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Cass Co. (H. S. Pepoon, 1905); Monroe Co. (C. K. Dodge, 1911); Wayne Co. (Lewis Foote, 1870); Washtenaw Co. (M. V. Harrington, 1868); Jackson Co. (S. H. & D. R. Camp, 1897); Calhoun Co. (W. J. Beal, 1898); Kalamazoo Co. (A. B. Burgess, 1903); Eaton Co. (H. T. Darlington, 1916); Ingham Co. (1887); Oakland Co. (C. Billington, 1918); St. Clair Co. (C. K. Dodge, 1892); Genesee Co., Ionia Co. (C. F. Wheeler, 1890); Muskegon Co. (W. J. Beal, 1898); Montcalm Co. (C. F. Wheeler, 1900); Gratiot Co. (C. A. Davis, 1893); Newaygo Co. (E. A. Bessey, 1916); Leelanau Co. (Pearl McCoy, 1917); Cheboygan Co. (J. H. Ehlers, 1920); Emmet Co. (H. M. Bailey, 1891).

Reported from Kent Co. (Emma J. Cole); Genesee Co. (M. A. C. identification); Huron Co., Charity Islands, Tuscola Co., Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co (F. P. Daniels); Charlevoix Co. (E. A. Bessey).

2. Cynoxylon Raf.

(Greek, 'dogwood')

Cynoxylon floridum (L.) Raf. ('flowering')
Cornus florida L.
Flowering Dogwood.
Oak woods, limited, with one exception, to the counties south of Saginaw Bay.

Specimens examined. — Berrien Co. (J. Colvin, 1906); St. Joseph Co. (A. B. Burgess, 1903); Van Buren Co. (H. S. Pepoon, 1903); Washtenaw Co. (A. J. Pieters, 1894) ; Wayne Co. (C. Billington, 1914); Macomb Co. (D. Cooley, 1844); Ingham Co. (L. J. Cole, 1895); Kent Co. (H. M. Bailey, 1891); Muskegon Co. (C. D. McLouth, 1896); Tuscola Co. (C. K. Dodge, 1910).

Reported from Lenawee Co. (Frances Stearns); Calhoun Co. (C. E. Barr); Allegan Co. (E. A. Bessey); Oakland Co. (J. W. Stacey); Manistee Co. (F. P. Daniels).

3. Chamaepericlymenum Graebn.

(Greek, 'ground Periclymenum')

Chamaepericlymenum canadense (L.) Asch. & Graebn. ('of Canada')

Cornus canadensis L.

Dwarf Cornel; Bunchberry.

All over state in bogs and cold woods.

Specimens examined. — Cass Co. (H. S. Pepoon, 1904); St. Joseph Co. (C. F. Wheeler, 1890); Washtenaw Co. (R. Walcott, 1891); Kalamazoo Co. (F. H. Tuthill, 1873); Macomb Co. (D. Cooley, 1843); Oakland Co. (B. F. Chandler, 1913); Ingham Co. (1871); Ottawa Co. (L. J. Cole, 1894); Clinton Co. (C. F. Wheeler, 1901); St. Clair Co. (C. K. Dodge, 1892); Muskegon Co. (W. J. Beal, 1898); Mason Co. (R. W. Chaney, 1910); Roscommon Co. (W. J. Beal, 1902); Alcona Co. (1888); Leelanau Co. (Anna King, 1920); Charlevoix Co. (E. A. Bessey, 1912); Cheboygan Co. (F. C. Gates, 1911); Emmet Co. (H. M. Bailey, 1893); Mackinac Co. (J. H. Ehlers, 1920); Mackinac Is. (C. F. Millspaugh, 1898); Chippewa Co. (J. H. Ehlers, 1920); Alger Co. (C. F. Wheeler, 1900); Marquette Co. (B. Barlow, 1901); Menominee Co. (J. H. Schuette, 1884); Baraga Co. (H. M. Bailey, 1893); Keweenaw Co. (F. E. Wood, 1883); Isle Royale (M. W. Harrington, 1868).

Reported from Van Buren Co. (H. S. Pepoon); Calhoun Co. (C. E. Barr); Kent Co. (Emma J. Cole); Huron Co., Tuscola Co. (C. A. Davis); Charity Islands, Bay Co. to Mackinac Co. along coast, Mackinac Island (C. K. Dodge); Manistee Co. (F. P. Daniels); Benzie Co. (W. G. Waterman); Beaver Island (H. T. Darlington); Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons); Gogebic Co., Ontonagon Co. (H. T. Darlington).

4. Nyssa L.

(Name of a water nymph)

Nyssa sylvatica Marsh. ('belonging to the woods')

Black Gum; Sour Gum; Tupelo; Pepperidge.

Swamps and swamp margins, almost confined to counties south of Saginaw Bay.

Specimens examined. — Cass Co. (H. S. Pepoon, 1906); Branch Co. (A. C. Burrell, 1914); Monroe Co. (C. D. La Rue, 1914); Wayne Co. (C. Billington, 1914); Washtenaw Co. (B. A. Walpole, 1920); Jackson Co. (S. H. Camp, 1893); Calhoun Co. (W. J. Beal, 1898); Van Buren Co. (H. S. Pepoon, 1903); Ingham Co. (W. J. Beal, 1899); Oakland Co. (C. Billington, 1916); Macomb Co. (D. Cooley, 1820); St. Clair Co. (C. K. Dodge, 1892); Saginaw Co. (A. J. Pieters, 1914); Gratiot Co. (C. A. Davis, 1890); Muskegon Co. (W. J. Beal, 1898).

Reported from Kalamazoo Co. (F. H. Tuthill); Kent Co. (Emma J. Cole); Tuscola Co., Bay Co., Arenac Co. (C. K. Dodge); Manistee Co. (F. P. Daniels).

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DISTRIBUTION OF THE ERICALES IN MICHIGAN

L. A. KENOYER

The order Ericales has 39 species reported from Michigan, all but one of which are native. The Michigan species constitute only 46 per cent of the 84 species included in the Britton & Brown *Illustrated Flora.* Their range is as follows:

	Listed in Britton & Brown	Found in Michigan
Eastern species	48	13
Western species	2	1
Northern species	30	22
Continent-wide species	2	2
Local species	1	0
Introduced species	1	1

The continent-wide species are *Monotropa uniflora* and *Chimaphila corymbosa.* The distribution of the order, so far as eastern North America is concerned, is prevailingly eastern and northern. The prairie states are almost without representatives. Of those species found in Michigan the northern, i.e., the arctic and subarctic, forms predominate. These are relicts of the glacial period, constituting a conspicuous element in the bog vegetation, a type of plant formation characteristic of the tundra and presumably stranded in a region now south of its natural climatic zone as the glaciers receded to the north.

All of our representatives belong to that assemblage of groups included by the earlier botanists and by Gray's *Manual* under the Ericaceae or Heath Family, but divided by Britton & Brown into Pyrolaceae (Wintergreen Family), Monotropaceae (Indian Pipe Family), Ericaceae (Heath Family), and Vaccini-

aceae (Huckleberry Family). For the first three families the nomenclature of the *North American Flora*, Volume 29, published by the New York Botanical Gardens, is here employed, while for the last, that of the Britton & Brown *Illustrated Flora* is relied upon.

Ecologically the bog habitat predominates for the group in Michigan. About 10 of our species are confined to bogs, while as many as 19 are to be found growing in bogs. Four may be found prevailingly as xerarch pioneers on sandy or rocky situations, where they take part in the formation of the so-called heath society, and 10 are found prevailingly in subclimax forests. It is doubtful whether any of them occur prevailingly in the climax beech-maple forest of southern and north central Michigan, but three are found in the northern birch-fir-spruce climax forest of Isle Royale. This accords with the general rule that climax members in the north tend to be pushed away from the climax as one proceeds southward.

Three members of the Heath Family proper are characteristic shrubs of the bog-shrub zone, which occurs in practically every bog of the state just outside (subsequently to, as regards time succession) the floating sedge mat and inside (previous to) the bog forest. The Bog Rosemary, *Andromeda polifolia*, appears first, growing on the sedge mat. Next comes Cassandra, *Chamaedaphne calyculata*, which may be considered the type shrub of the bog-shrub zone. Last is Labrador Tea (*Ledum groenlandicum*), which roots itself in the sphagnum and by killing out the other shrubs and eventually even the sphagnum occupies the ground until trees take possession. This is less common in the southern part of the state than are the other two.

Other bog shrubs of importance in the order are the cranberries, *Oxycoccus oxycoccus* and *Oxycoccus macrocarpus*, the High Blueberry, *Vaccinium corymbosum*, and, in the northern portion, the Creeping Snowberry, *Chiogenes hispidula*.

The Bearberry, *Uva-ursi uva-ursi*, is one of the prevailing members of the sand-dune heath formation, while *Vaccinium caespitosum* and *V. uliginosum* are rock pioneers in the northern part of the state.

The Huckleberry, *Gaylussacia resinosa*, and the low blueberries, *Vaccinium angustifolium* and *V. canadense*, are among the forms characteristic of dry or sandy pioneer formations although they, particularly the last, may also be found in bogs.

Of our species 18 are state-wide in their distribution, 11 are more or less restricted to the northern part, 4 to the southern part, while 6 are local or scattering.

Because of the preponderance of northern forms this order enters prominently into any plant list from the Upper Peninsula. There are only 3.4 times as many localities reported for the species of this order from the Lower as from the Upper Peninsula, as compared with 6.5 times as many which we found in the case of the Umbellales.

A rare shrub of the order is *Arsenococcus ligustrinus*, which was found in Keweenaw County by Dr. Robbins and in Newaygo by Prof. Darlington. Another is *Polycodium stamineum*, found in Washtenaw by C. A. Davis. *Vaccinium membranaceum*, *V. ovalifolium* and *V. uliginosum* are of very limited distribution in the northern part of the state, while *V. caespitosum* has been reported only from Ionia County and indefinitely from northern Michigan. *Erxlebenia minor* has been found only on Isle Royale and in Cheboygan County. *Vitis-idaea vitis-idaea* has been collected only on Isle Royale. A more thorough exploration of northern Michigan would doubtless reveal other forms.

ERICALES

Carpels many with many minute seeds; style 1; petals united or separate; stamens as many as the corolla lobes or petals and alternate with them; anthers commonly appendaged or opening by terminal pores.

Saprophytes or root parasites, without green foliage
2. *Monotropaceae* (Indian Pipe Family).
Green plants.
  Petals separate .... 1. *Pyrolaceae* (Wintergreen Family).
  Petals united.
    Ovary superior.............. 3. *Ericaceae* (Heath Family).
    Ovary inferior.............. 4. *Vacciniaceae* (Huckleberry Family).

I. *PYROLACEAE* (Wintergreen Family)

Flowers solitary....................................4. *Moneses*
Flowers clustered.
  Flowers in racemes; leaves basal.
    Style curved downward..............................1. *Pyrola.*
    Style straight.
      Style short; disk none..........................2. *Erxlebenia.*
      Style long; disk 10-lobed.......................3. *Ramischia.*
  Flowers in corymbs or umbels; leaves opposite or whorled.
    5. *Chimaphila.*

1. Pyrola [Tourn.] L. Wintergreen

(Diminutive of *pyrus*, 'pear,' from similarity of leaves)

Flowers pink or purple; bog plants.
  Leaves round or oval...............................1. *P. uliginosa.*
  Leaves reniform....................................2. *P. asarifolia.*
Flowers white or greenish; woodland plants.
  Calyx lobes lanceolate, acute; leaves shining..........3. *P. americana.*
  Calyx lobes triangular or ovate, obtuse; leaves dull.
    Leaves elliptical; blade longer than petiole..........4. *P. elliptica.*
    Leaves orbicular; blade shorter than petiole.........5. *P. chlorantha.*

1. *Pyrola uliginosa* Torr. ('of damp places')
Pyrola asarifolia incarnata (Fisch.) Fernald.
Bog Wintergreen.
In bogs, over most of the state.

Specimens examined. — Jackson Co. (S. H. & D. R. Camp, 1894); Washtenaw Co. (N. H. Winchell, 1862); Ingham Co. (H. C. Skeels, 1894); Oakland Co. (B. F. Chandler, 1916); St. Clair Co. (C. K. Dodge, 1893); Gratiot Co. (C. A. Davis, 1893); Montcalm Co. (Quackenbush, 1890); Muskegon Co. (C. D. McLouth, 1895); Mason Co. (R. W. Chaney, 1910); Iosco Co. (Beal & Wheeler, 1888); Alcona Co. (1888); Alpena Co. (C. F. Wheeler, 1895); Cheboygan Co. (C. K. Dodge, 1912); Emmet Co. (R. Rowland, 1893); Alger Co. (C. K. Dodge, 1916); Marquette Co. (B. Barlow, 1901); Menominee Co. (I. B. Schuette, 1891); Isle Royale (A. E. Foote, 1868).

Reported from Eaton Co. (H. L. Clark); Livingston Co. (C. A. Davis); Alpena Co. to Mackinac Co. along coast, Schoolcraft Co. (C. K. Dodge); Dickinson Co. (E. J. Hill); Keweenaw Co. (O. A. Farwell).

2. *Pyrola asarifolia* Michx. ('with leaves like *Asarum*,' the wild ginger.) Liver-leaf Wintergreen.

In bogs, like the former species, and apparently grading into it.

Specimen examined. — Schoolcraft Co. (C. K. Dodge, 1915).

Reported from Oakland Co. (J. W. Stacey); Kent Co. (Bert E. Quick); Bay Co. to Mackinac Co. along coast, Mackinac Island (C. K. Dodge); Cheboygan Co. (F. C. Gates); Emmet Co. (Fallass & Swift); Gogebic Co. (H. T. Darlington); Isle Royale (W. S. Cooper).

3. *Pyrola americana* Sweet. ('American')
Round-leaved American Wintergreen.

Dry woods, in Lower Peninsula only.

Specimens examined. — Berrien Co. (G. S. Ames, 1867); Cass Co. (H. S. Pepoon, 1906); Hillsdale Co. (1868); Washtenaw Co. (B. A. Walpole, 1918); Ingham Co. (1872); Oakland Co. (B. F. Chandler, 1916); St. Clair Co. (C. K. Dodge, 1892); Muskegon Co. (W. J. Beal, 1898); Oceana Co. (D. Cooley, 1848); Mason Co. (Bessey & Darlington, 1916); Alpena Co. (C. F. Wheeler, 1895); Cheboygan Co. (F. C. Gates, 1916); Emmet Co. (Russell Rowland, 1893).

Reported from Wayne Co. (O. A. Farwell, "rare"); Kent Co. (C. W. Fallass); Huron Co., Charity Islands, Tuscola Co. (C. K. Dodge); Isabella Co. (M. A. C. identification); Manistee Co. (F. P. Daniels); Leelanau Co. (E. A. Bessey).

4. *Pyrola elliptica* Nutt. ('elliptic')
Shin Leaf.

All over state, in forests.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Cass Co. (H. S. Pepoon, 1906); Lenawee Co. (W. J. Beal, 1866); Wayne Co. (Lewis Foote, 1870); Jackson Co. (S. H. & D. R. Camp, 1897); Kalamazoo Co. (R. M. Gibbs); Ingham Co. (F. L. Sleeper, 1867); Oakland Co. (C. Billington, 1914); St. Clair Co. (C. K. Dodge, 1892); Montcalm Co. (C. F. Wheeler, 1900); Isabella Co. (Mrs. E. B. Cole, 1914);

Mason Co. (Bessey & Darlington, 1916); Iosco Co. (Beal & Wheeler, 1888); Alpena Co. (C. F. Wheeler, 1895); Leelanau Co. (Anna King, 1920); Cheboygan Co. (J. H. Ehlers, 1920); Mackinac Island (C. F. Millspaugh, 1898); Alger Co. (J. G. Coulter, 1892); Menominee Co. (C. A. Davis, 1905); Marquette Co. (B. Barlow, 1901); Gogebic Co. (H. T. Darlington, 1919); Keweenaw Co. (O. A. Farwell, 1886); Isle Royale (A. E. Foote, 1868).

Reported from Calhoun Co. (C. E. Barr); Washtenaw Co. (C. D. La Rue); Kent Co. (B. F. Livingston); Ionia Co. (Beal's catalog); Huron Co. (C. A. Davis); Charity Islands, Tuscola Co., Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); Charlevoix Co. (L. H. Harvey); Emmet Co. (C. W. Fallass); Schoolcraft Co. (C. K. Dodge).

5. *Pyrola chlorantha* Sweet. ('green-flowered')

Greenish-flowered Wintergreen.

Woods, especially northward; not very abundant.

Specimens examined. — Ingham Co. (1872); Kent Co. (W. E. Millikan, 1896); Ionia Co. (D. Cooley, 1847); St. Clair Co. (C. K. Dodge, 1893); Grand Traverse Co. (C. F. Wheeler, 1898); Oscoda Co. (1888); Alpena Co. (C. F. Wheeler, 1895); Cheboygan Co. (C. F. Wheeler, 1890); Emmet Co. (Fallass & Swift, 1918); Mackinac Co. (C. K. Dodge, 1912); Chippewa Co. (C. K. Dodge, 1914); Ontonagon Co. (H. T. Darlington, 1922); Keweenaw Co. (O. A. Farwell, 1888); Isle Royale (A. E. Foote, 1868).

Reported from Gratiot Co. (W. J. Beal); Mackinac Island (C. K. Dodge); Marquette Co., Gogebic Co. (E. A. Bessey).

2. Erxlebenia Opiz.

Erxlebenia minor (L.) Rydberg ('lesser')

Pyrola minor L.

Lesser Wintergreen.

Forests; almost limited to the Upper Peninsula.

Specimens examined. — Chippewa Co. (Lewis Foote, 1868); Alger Co. (K. K. Mackenzie, 1916, "plentiful").

Reported from Cheboygan Co. (F. C. Gates); Keweenaw Co. (O. A. Farwell); Isle Royale (W. S. Cooper, climax or fir-birch-spruce forest).

3. Ramischia Opiz.

Ramischia secunda (L.) Garcke. ('one-sided')

Pyrola secunda L.

One-sided Wintergreen.

All over state in swamps and moist woods.

Specimens examined. — Cass Co. (H. S. Pepoon, 1906); Wayne Co. (Lewis Foote, 1870); Washtenaw Co. (B. A. Walpole, 1918); Jackson Co. (S. H. & D. R. Camp, 1899); Ingham Co. (H. T. Darlington, 1916); Oakland Co. (C. Billington, 1914); St. Clair Co. (C. K. Dodge, 1891); Lapeer Co. (D. Cooley, 1847); Genesee Co. (D. Clark); Kent Co. (L. H. Cole, 1896); Muskegon Co. (C. D. McLouth, 1898); Mason Co. (H. T. Blodgett, 1892); Roscommon Co. (Bessey & Darlington, 1916); Iosco Co. (Beal & Wheeler, 1888); Alcona Co. (1888); Grand Traverse Co. (C. F. Wheeler, 1898); Cheboygan Co. (C. F. Wheeler, 1890); Emmet Co. (Hathaway); Mackinac Co. (C. K. Dodge, 1912); Mackinac Island (C. F. Millspaugh, 1898); Alger Co. (C. F. Wheeler, 1900); Marquette Co. (B. Barlow, 1901); Menominee Co. (C. A. Davis, 1905); Gogebic Co. (E. A. Bessey, 1919); Ontonagon Co. (H. T. Darlington, 1922); Isle Royale (J. H. Sandberg, 1889).

Reported from Van Buren Co. (H. S. Pepoon); St. Joseph Co. (F. P. Daniels); Huron Co., Charity Islands, Tuscola Co., Bay Co. to Mackinac Co. along coast, Mackinac Island (C. K. Dodge); Manistee Co. (F. P. Daniels); Crawford Co. (G. H. Hicks); Charlevoix Co. (L. H. Harvey); Beaver Island (H. T. Darlington); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Delta Co. (E. J. Hill); Keweenaw Co. (O. A. Farwell); Isle Royale (W. S. Cooper).

4. Moneses Salisb.

(Greek, 'single delight')

Moneses uniflora (L.) A. Gray ('one-flowered')
One-flowered Wintergreen.

Mainly northward, in damp woods and swamps.

Specimens examined. — Ingham Co. (H. T. Darlington, 1916); St. Clair Co. (C. K. Dodge, 1892); Alpena Co. (C. F. Wheeler, 1895); Cheboygan Co. (C. F. Wheeler, 1890); Emmet Co. (collector unknown); Chippewa Co. (C. K. Dodge, 1914); Schoolcraft Co. (C. K. Dodge, 1915); Menominee Co. (J. H. Schuette, 1884); Marquette Co. (B. Barlow, 1901); Gogebic Co. (E. A. Bessey, 1919); Keweenaw Co. (O. A. Farwell, 1886); Isle Royale (A. E. Foote, 1868).

Reported from Oakland Co. (J. W. Stacey); Genesee Co., Montcalm Co. (Beal's catalog); Tuscola Co., Bay Co. to Mackinac Co. along coast (C. K. Dodge); Delta Co. (E. J. Hill).

5. Chimaphila Pursh.

(Greek, 'winter-loving,' from the evergreen leaves.)

Leaves lanceolate, mottled .... 1. *C. maculata.*
Leaves spatulate, bright green .... 2. *C. corymbosa.*

1. *Chimaphila maculata* (L.) Pursh. ('spotted')
Spotted Wintergreen.

Woods, mainly in the southwest near Lake Michigan.

Specimens examined. — Cass Co. (H. S. Pepoon, 1906); Van Buren Co. (H. S. Pepoon, 1904); Allegan Co. (C. Billington, 1917); Ottawa Co. (Lewis Foote, 1871); Washtenaw Co. (B. A. Walpole, 1919); Mason Co. (R. W. Chaney, 1910); Leelanau Co. (Anna King, 1920).

Reported from Genesee Co. (Beal's catalog); Ionia Co. (L. H. Bailey); Muskegon Co. (Mary J. Fallass).

2. *Chimaphila corymbosa* Pursh. ('flowers in corymbs')
Chimaphila umbellata of Gray's *Manual* and Britton & Brown's *Flora.* (The latter name is now reserved for a European species slightly different from ours.)

All over the state in oak and pine forests.

Specimens examined. — Cass Co. (F. C. Gates, 1906); Van Buren Co. (H. S. Pepoon); Calhoun Co. (W. J. Beal, 1898); Jackson Co. (S. H. & D. R. Camp, 1897); Washtenaw Co. (C. D. La Rue, 1915); Ingham Co. (1875); Oakland Co. (B. F. Chandler, 1916); St. Clair Co. (C. K. Dodge, 1892); Kent Co. (Shaddick & Skeels, 1895); Montcalm Co. (B. Barlow, 1900); Gratiot Co. (1890); Oceana Co. (Lewis Foote, 1870); Mason Co. (R. W. Chaney, 1910); Missaukee Co. (C. D. La Rue, 1914); Crawford Co. (G. H. Hicks, 1888); Leelanau Co. (Anna King, 1920); Cheboygan Co. (J. H. Ehlers, 1917); Emmet Co. (C. F. Wheeler, 1890); Beaver Island (C. F. Wheeler, 1900); Mackinac Island (C. F. Millspaugh, 1898); Delta Co. (H. H. Babcock, 1872); Marquette Co. (A. Dachnowski, 1906) Gogebic Co. (Bessey & Darlington, 1919); Ontonagon Co. (H. T. Darlington, 1922); Isle Royale (A. E. Foote, 1868).

Reported from St. Joseph Co. (F. P. Daniels); Allegan Co. (E. A. Bessey); Muskegon Co. (C. D. McLouth); Huron Co. (C. A. Davis); Charity Islands, Tuscola Co., Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (L. H. Harvey); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons).

II. *MONOTROPACEAE* (Indian Pipe Family)

Petals united, persistent .... 1. *Pterospora.*
Petals separate, deciduous.
  Flowers solitary .... 2. *Monotropa.*
  Flowers in racemes .... 3. *Hypopitys.*

1. Pterospora Nutt.

(Greek, 'wing-seeded')

Pterospora andromedea Nutt. ('dedicated to Andromeda')
Pine Drops; Giant Bird's Nest.

Widely scattered, among pines, on the roots of which it is parasitic. Not common.

Specimens examined. — St. Clair Co. (C. K. Dodge, 1892);

Ottawa Co. (Lewis Foote, 1871); Antrim Co. (W. S. Cooper, 1902); Emmet Co. (J. H. Ehlers, 1920).

Reported from Iosco Co. (Beal's catalog); Schoolcraft Co. (C. K. Dodge); Ontonagon Co. (E. Whitney); Keweenaw Co. (O. A. Farwell).

2. Monotropa L.

(Greek, 'once-turned')

Monotropa uniflora L. ('one-flowered')

Indian Pipe.

Over entire state, in rich forests.

Specimens examined. — Berrien Co. (Miss Everts, 1867); Cass Co. (H. S. Pepoon, 1906); Van Buren Co. (H. S. Pepoon, 1906); Lenawee Co. (W. J. Beal, 1866); Washtenaw Co (C. D. La Rue, 1915); Wayne Co. (Mabel C. Riggs); Oakland Co. (C. Billington, 1914); Ingham Co. (F. L. Sleyser, 1867); St. Clair Co. (C. K. Dodge, 1892); Genesee Co. (J. S. Spencer, 1896); Ottawa Co. (E. B. W., 1891); Montcalm Co. (C. F. Wheeler, 1900); Mason Co. (R. W. Chaney, 1910); Leelanau Co. (Anna King, 1920); Cheboygan Co. (C. K. Dodge, 1896); Beaver Island (C. F. Wheeler, 1900); Mackinac Island (C. F. Millspaugh, 1898); Mackinac Co. (S. H. & D. R. Camp, 1896); Menominee Co. (J. H. Schuette, 1885); Marquette Co. (B. Barlow, 1901); Gogebic Co. (E. A. Bessey, 1919); Ontonagon Co. (H. T. Darlington, 1922); Keweenaw Co. (O. A. Farwell, 1886); Isle Royale (A. E. Foote, 1868).

Reported from St. Joseph Co. (F. P. Daniels); Branch Co., Hillsdale Co. (M. A. C. identifications); Calhoun Co. (C. E. Barr); Kalamazoo Co., Allegan Co., Barry Co., Livingston Co. (M. A. C. identifications); Kent Co. (C. W. Fallass); Muskegon Co. (C. D. McLouth); Tuscola Co., Huron Co. (C. K Dodge); Charity Islands (N. A. Wood); Osceola Co. (M. A. C. identification); Manistee Co. (F. P. Daniels); Emmet Co. (C. W. Fallass); Mackinac Co., Mackinac Island (C. K. Dodge); Chippewa Co. (H. A. Wood); Schoolcraft Co. (C. K. Dodge).

3. Hypopitys Adans.

(Greek, in reference to its growth under firs)

Hypopitys lanuginosa (Michx.) Nutt. ('woolly')
Montropa hypopitys Gray's *Manual.*
Hairy Pinesap; False Beech Drops.
Scattered over most of the state, but especially rare in the jack pine region.

Specimens examined. — Cass Co. (H. S. Pepoon, 1904); Washtenaw Co. (C. D. La Rue, 1915); Ingham Co. (C. F. Wheeler, 1901); Oakland Co. (B. F. Chandler, 1915); Macomb Co. (D. Cooley, 1848); Manistee Co. (F. P. Daniels, 1900); Cheboygan Co. (C. K. Dodge, 1892); Marquette Co. (A. Dachnowski, 1906); Gogebic Co. (H. T. Darlington, 1919); Keweenaw Co. (O. A. Farwell, 1887).

Reported from St. Clair Co. (Whitney catalog); Crawford Co. (G. H. Hicks); Emmet Co. (C. W. Fallass); Chippewa Co. (C. K. Dodge); Delta Co. (E. J. Hill); Ontonagon Co. (Whitney catalog); Isle Royale (W. S. Cooper).

III. *ERICACEAE* (Heath Family)

KEY BASED ON FRUIT CHARACTERS

Fruit dry.
  Fruit a septicidal capsule.
    Corolla withering-persistent . . . . 9. *Calluna.*
    Corolla deciduous.
      Flowers from scaly buds; petals separate . . . . 1. *Ledum.*
      Flowers not from scaly buds; petals united . . . . . . 2. *Kalmia.*
  Fruit a loculicidal capsule.
    Pollen sacs opening only at the top.
      Anthers 2–4-awned . . . . 4. *Andromeda.*
      Anthers awnless.
        Capsule wall splitting into two layers . . . . 3. *Chamaedaphne.*
        Capsule wall of one layer only . . . . 5. *Arsenococcus.*
    Pollen sacs splitting longitudinally . . . . 6. *Epigaea.*
Fruit fleshy.
  Fruit a capsule surrounded by a fleshy calyx . . . . 7. *Gaultheria.*
  Fruit a drupe with several cohering 1-seeded nutlets . . 8. *Uva-ursi.*

KEY BASED ON LEAF CHARACTERS

Leaves opposite or whorled.
  Leaves minute, scale-like, overlapping..............9. *Calluna.*
  Leaves not as above..............................2. *Kalmia.*
Leaves alternate.
  Leaf margins strongly revolute.
    Leaves brown-woolly beneath...................1. *Ledum.*
    Leaves white-woolly beneath...................4. *Andromeda.*
  Leaf margins not strongly revolute.
    Leaves glabrous or nearly so.
      Tall shrub or small tree.......................5. *Arsenococcus.*
      Low shrubs.
        Leaves serrate.............................7. *Gaultheria.*
        Leaves entire..............................8. *Uva-ursi.*
    Leaves not glabrous.
      Leaves covered with scurfy scales.............3. *Chamaedaphne.*
      Leaves woolly beneath, smooth above..........6. *Epigaea.*

1. Ledum L.

(Greek name of the Cistus)

Ledum groenlandicum Oeder ('of Greenland')
Labrador Tea.

An Arctic species found in bogs, particularly in the northern portion of the state.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Ingham Co. (Tracy, 1865); Oakland Co. (C. Billington, 1917); Iosco Co. (Beal & Wheeler, 1888); Roscommon Co. (F. G. Gustafson, 1922); Missaukee Co. (Bessey & Darlington, 1916); Crawford Co. (G. H. Hicks, 1888); Otsego Co. (C. Billington, 1914); Alpena Co. (Bessey & Darlington, 1918); Emmet Co. (F. C. & M. T. Gates, 1917); Cheboygan Co. (J. H. Ehlers, 1920); Mackinac Co. (J. H. Ehlers, 1916); Chippewa Co. (C. K. Dodge, 1914); Schoolcraft Co. (C. A. Davis, 1905); Alger Co. (C. F. Wheeler, 1900); Marquette Co. (B. Barlow, 1901); Gogebic Co. (E. A. Bessey, 1919); Keweenaw Co. (O. A. Farwell, 1886).

Reported from Kent Co. (L. S. Livingston); Huron Co., Tuscola Co., Bay Co. to Mackinac Co. along coast, Mackinac Island (C. K. Dodge); Benzie Co. (W. S. Waterman); Charlevoix Co. (E. A. Bessey); Emmet Co. (C. W. Fallass); N.

Manitou Island (E. N. Transeau); Beaver Island (H. T. Darlington); Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons); Ontonagon Co. (H. T. Darlington); Isle Royale (W. S. Cooper).

2. Kalmia L.

(Named for Peter Kalm, a pupil of Linnaeus)

Flowers in lateral mostly compound corymbs; twigs terete 1. *K. angustifolia.*
Flowers in terminal simple corymbs; twigs 2-angled....2. *K. polifolia.*

1. *Kalmia angustifolia* L. ('narrow-leaved')
Sheep Laurel; Lambkill.
Swamps or open woods; almost restricted to a group of counties northwest of Saginaw Bay.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Bay Co. (George T. Benson, 1918); Arenac Co. (C. F. Wheeler, 1900); Roscommon Co. (C. Billington, 1919); Crawford Co. (1888); Oscoda Co. (Beal & Wheeler, 1888); Alcona Co. (1888); Alpena Co. (C. F. Wheeler, 1895).

Reported from Arenac to Alpena Cos., especially Arenac and Iosco (C. K. Dodge); Mackinac Co. (M. A. C. identification).

2. *Kalmia polifolia* Wang ('smooth-leaved')
Pale or Swamp Laurel.
Shrub zone of bogs, mostly in the northern portion. Not reported from the two southern tiers of counties.

Specimens examined. — Oakland Co. (B. F. Chandler, 1917); St. Clair Co. (C. K. Dodge, 1904); Ionia Co. (C. F. Wheeler, 1876); Missaukee Co. (A. L. Entrican, 1915); Grand Traverse Co. (Irish, 1892); Crawford Co. (G. H. Hicks, 1888); Oscoda Co. (H. T. Darlington, 1918); Cheboygan Co. (C. A. Kofoid, 1890); Chippewa Co. (C. K. Dodge, 1914); Alger Co. (J. G. Coulter, 1892); Marquette Co. (B. Barlow, 1901); Gogebic Co. (H. T. Darlington, 1919); Keweenaw Co. (Lewis Foote, 1865); Isle Royale (A. E. Foote, 1868).

Reported from Macomb Co. (W. J. Beal); Huron Co., Tuscola Co., Bay Co. to Mackinac Co. along coast (C. K. Dodge); Osceola Co. (M. A. C. identification); Manistee Co. (F. P. Daniels, 1902); Emmet Co. (Fallass & Swift); N. Manitou Island (E. N. Transeau); Beaver Island (H. T. Darlington); Schoolcraft Co. (C. K. Dodge).

3. Chamaedaphne Moench.

(Greek, 'ground Daphne')

Chamaedaphne calyculata (L.) Moench. ('with small cups')
Leather Leaf; Cassandra.

Shrub zone of bogs in all parts of the state.

Specimens examined. — Lenawee Co. (W. J. Beal, 1868); Washtenaw Co. (C. D. La Rue, 1915); Jackson Co. (S. H. & D. R. Camp, 1898); Calhoun Co. (W. J. Beal, 1898); Kalamazoo Co. (Walbridge, 1877); Van Buren Co. (H. S. Pepoon, 1905); Ingham Co. (L. J. Cole, 1895); Oakland Co. (A. Senier, 1873); St. Clair Co. (C. K. Dodge, 1896); Gratiot Co. (1892); Muskegon Co. (W. J. Beal, 1898); Newaygo Co. (H. T. Darlington, 1916); Mason Co. (R. W. Chaney, 1910); Arenac Co. (C. F. Wheeler, 1900); Missaukee Co. (E. A. Bessey, 1916); Crawford Co. (G. H. Hicks, 1888); Alcona Co. (Bessey & Darlington, 1918); Cheboygan Co. (J. H. Ehlers, 1917); Marquette Co. (B. Barlow, 1901); Gogebic Co. (H. T. Darlington, 1919); Isle Royale (A. E. Foote, 1868).

Reported from Cass Co. (H. S. Pepoon); St. Joseph Co. (F. P. Daniels); Kent Co. (E. J. Cole); Tuscola Co. (C. K. Dodge); Huron Co. (C. A. Davis); Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); Benzie Co. (W. G. Waterman); Leelanau Co. (S. M. Coulter); N. Manitou Island (E. N. Transeau); Charlevoix Co. (E. A. Bessey); Emmet Co. (Fallass & Swift); Beaver Island (H. T. Darlington); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons); Ontonagon Co. (H. T. Darlington).

4. Andromeda L.

(Named for Andromeda of mythology)

Andromeda polifolia L. ('smooth-leaved')
Andromeda glaucophylla Link.
Bog Rosemary; Moorwort.
All over the state in the shrub zone of bogs.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Van Buren Co. (H. S. Pepoon, 1906); Calhoun Co. (W. J. Beal, 1898); Washtenaw Co. (V. M. Spalding, 1880); Oakland Co. (C. Billington, 1914); Ingham Co. (W. J. Beal, 1870); Ionia Co. (C. F. Wheeler, 1887); Genesee Co. (D. Clark); St. Clair Co. (C. K. Dodge, 1904); Mason Co, (R. W. Chaney, 1910); Missaukee Co. (H. T. Darlington, 1916); Crawford Co. (G. H. Hicks, 1888); Oscoda Co. (H. T. Darlington, 1918); Alpena Co. (Bessey & Darlington, 1918); Antrim Co. (collector unknown); Cheboygan Co. (J. H. Ehlers, 1916); Emmet Co. (J. H. Ehlers, 1921); Chippewa Co. (C. K. Dodge, 1914); Marquette Co. (B. Barlow, 1901); Dickinson Co. (C. A. Davis, 1905); Baraga Co. (S. R. Bailey, 1893); Gogebic Co. (H. T. Darlington, 1919); Keweenaw Co. (O. A. Farwell, 1886); Isle Royale (University party, 1868).

Reported from Cass Co. (H. S. Pepoon); Eaton Co. (H. L. Clark); Kent Co. (Emma J. Cole); Huron Co., Tuscola Co., Bay Co. to Mackinac Co. along coast (C. K. Dodge); Benzie Co. (W. G. Waterman); N. Manitou Island (E. N. Transeau); Beaver Island (H. T. Darlington); Schoolcraft Co. (C. K. Dodge).

5. Arsenococcus Small.

Arsenococcus ligustrinus (L.) Small ('like the privet')
Xolisma ligustrina (L.) Britton.
Lyonia ligustrina (L.) DC.
Privet Andromeda; Male Berry.
Through the Atlantic region; rare in Michigan.

Specimen examined. — Newaygo Co. (H. T. Darlington).
Reported from Keweenaw Co. (Dr. Robbins).

6. Epigaea L.

(Greek, 'on the earth')

Epigaea repens L. (creeping)

Trailing Arbutus; Mayflower; Ground Laurel.

Dry forests, dunes and bogs, particularly northward.

Specimens examined. — Washtenaw Co. (B. A. Walpole, 1918); Oakland Co. (C. Billington, 1919); Ingham Co. (1871); Allegan Co. (L. A. Kenoyer, 1923); St. Clair Co. (C. Ferraud, 1866); Muskegon Co. (C. Billington, 1915); Isabella Co. (C. A. Davis, 1894); Mason Co. (Miss G. Rogers); Grand Traverse Co. (C. F. Wheeler, 1898); Crawford Co. (G. H. Hicks, 1888); Oscoda Co. (1888); Alpena Co. (Bessey & Darlington, 1918); Emmet Co. (F. C. Gates, 1917); Cheboygan Co. (C. Billington, 1914); Alger Co. (C. F. Wheeler, 1900); Marquette Co. (B. Barlow, 1901); Gogebic Co. (E. A. Bessey, 1919); Ontonagon Co. (A. E. Foote, 1868); Keweenaw Co. (O. A. Farwell, 1887).

Reported from Berrien Co. (H. S. Pepoon); Jackson Co. (W. C. Hull); Kent Co. (Emma J. Cole); Huron Co. (C. A. Davis); Charity Islands (Chas. McDonald); Tuscola Co., Bay Co. to Mackinac Co. along coast, Mackinac Island (C. K. Dodge); Mecosta Co. (C. W. Fallass); Manistee Co. (F. P. Daniels); Emmet Co. (C. E. Barr); Chippewa Co., Schoolcraft Co. (C. K. Dodge).

7. Gaultheria Kalm.

(Named for Dr. Gaultier of Quebec)

Gaultheria procumbens L. ('prostrate')

Spring, Creeping or Spicy Wintergreen.

Bogs and dry woods, all over the state.

Specimens examined. — Berrien Co. (O. E. Lansing, Jr., 1911); Cass Co. (H. S. Pepoon, 1905); Branch Co. (1869); Monroe Co. (C. D. La Rue, 1914); Wayne Co. (Lewis Foote, 1870); Washtenaw Co. (B. A. Walpole, 1918); Jackson Co. (Miss Bennett); Calhoun Co. (W. J. Beal, 1898); Allegan Co. (L. A. Kenoyer, 1923); Ingham Co (F. L. Sleeper, 1868);

Oakland Co. (B. F. Chandler, 1916); St. Clair Co. (C. K. Dodge, 1892); Kent Co. (H. M. Bailey, 1891); Ottawa Co. (L. J. Cole, 1896); Muskegon Co. (W. J. Beal, 1898); Montcalm Co. (C. F. Wheeler, 1900); Gratiot Co. (C. A. Davis, 1889; Arenac Co. (C. F. Wheeler, 1900); Mason Co. (R. W. Chaney, 1910); Roscommon Co. (E. A. Bessey, 1916); Leelanau Co. (Anna King, 1920); Cheboygan Co. (J. H. Ehlers, 1916); Emmet Co. (C. F. Wheeler, 1890); Alger Co. (C. F. Wheeler, 1900); Marquette Co. (B. Barlow, 1901); Gogebic Co. (H. T. Darlington, 1919); Isle Royale (J. H. Ely, 1892).

Reported from Van Buren Co. (H. S. Pepoon); St. Joseph Co. (F. P. Daniels); Huron Co., Charity Islands, Tuscola Co., Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (L. H. Harvey); Benzie Co. (W. G. Waterman); N. Manitou Island (S. M. Coulter); Charlevoix Co. (E. A. Bessey); Beaver Island (H. T. Darlington); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons); Ontonagon Co. (H. T. Darlington).

8. Uva-ursi Mill.

(Latin 'bearberry')

Uva-ursi uva-ursi (L.) Britton.

Arctostaphylos uva-ursi (L.) Spreng.

Red Bearberry.

All over state, especially northward, on sand dunes and rock shores.

Specimens examined. — Jackson Co. (S. H. & D. R. Camp, 1893); Ingham Co. (1876); St. Clair Co. (C. K. Dodge, 1892); Shiawassee Co. (D. Clark, 1877); Ottawa Co. (L. J. Cole, 1895); Muskegon Co. (C. D. McLouth, 1901); Huron Co. (C. A. Davis, 1896); Mason Co. (Mrs. O. C. Nurnberg, 1915); Roscommon Co. (Cannon, 1844); Iosco Co. (Beal & Wheeler, 1888); Crawford Co. (C. F. Wheeler, 1898); Benzie Co. (1888); Leelanau Co. (Pearl McCoy, 1917); Charlevoix Co. (1881); Emmet Co. (C. F. Wheeler, 1879); Cheboygan Co. (C. Billington, 1914); Mackinac Island (C. F. Millspaugh, 1898); Mackinac

Co. (J. H. Ehlers, 1920); Alger Co. (J. G. Coulter, 1892); Marquette Co. (C. F. Wheeler, 1892); Gogebic Co. (C. A. Davis, 1905); Keweenaw Co. (O. A. Farwell, 1888); Isle Royale (A. E. Foote, 1868).

Reported from Allegan Co. (E. A. Bessey); Oakland Co. (J. W. Stacey); Kent Co. (Emma J. Cole); Newaygo Co. (E. A. Bessey); Bay Co. (E. A. Bessey); Charity Islands, Tuscola Co., Arenac to Mackinac Co. (C. K. Dodge); Manistee Co. (F. P. Daniels); N. Manitou Island, Beaver Island (H. C. Cowles); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons).

9. Calluna Salisb.

(from Greek, 'sweep,' the twigs being used for brooms)

Calluna vulgaris (L.) Salisb. ('common')

Heather; Ling.

Reported from Marquette Co., as a naturalized plant, probably introduced from Scotland (Collected by Mary B. Snyder, 1920–1, identified by Bessey & Darlington).

IV. *VACCINIACEAE* (Huckleberry Family)

Ovary 10-locular; leaves with resinous dots beneath....1. *Gaylussacia.*
Ovary 4–5-locular.
  Corolla not deeply cleft.
    Corolla open bell-shaped.
      Corolla 4-lobed; leaves small, evergreen............2. *Vitis-idaea.*
      Corolla 5-lobed; leaves large, deciduous............3. *Polycodium.*
    Corolla cylindric or urn-shaped.
      Erect shrubs....................................4. *Vaccinium.*
      Low trailing shrub..............................5. *Chiogenes.*
  Corolla deeply 4-cleft, reflexed........................6. *Oxycoccus.*

1. Gaylussacia H. B. K.

(Named for the chemist, Gay-Lussac)

1. *Gaylussacia baccata* (Wang.) K. Koch ('with berries')

Huckleberry.

Over state, in dry or sandy forests, less frequent in the Upper Peninsula.

Specimens examined. — Cass Co. (C. F. Wheeler, 1890); St. Joseph Co., Kalamazoo Co. (A. B. Burgess, 1903); Calhoun Co. (W. J. Beal, 1898); Jackson Co. (G. H. Hicks, 1893); Washtenaw Co. (E. C. Allmendinger); Wayne Co. (Lewis Foote, 1870); Oakland Co. (C. Billington, 1916); Livingston Co. (J. H. Ehlers, 1920); Ingham Co. (1872); Allegan Co. H. M. Bailey, 1891); St. Clair Co. (C. K. Dodge, 1886); Montcalm Co. (C. F. Wheeler, 1900); Muskegon Co. (W. J. Beal, 1898); Newaygo Co. (H. T. Darlington, 1916); Huron Co. (C. K. Dodge, 1909); Mason Co. (R. W. Chaney, 1910); Arenac Co. (C. F. Wheeler, 1900); Iosco Co. (H. T. Darlington, 1918); Crawford Co. (1888); Alpena Co. (Bessey & Darlington, 1918); Cheboygan Co. (C. K. Dodge, 1913); Marquette Co. (A. Dachnowski, 1906); Alger Co. (J. G. Coulter, 1892).

Reported from Berrien Co., Van Buren Co. (H. S. Pepoon); St. Joseph Co. (F. P. Daniels); Lenawee Co. (Frances Stearns); Kent Co. (C. W. Fallass); Tuscola Co. (C. A. Davis); Charity Islands, Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); Benzie Co. (W. G. Waterman); Emmet Co. (Fallass & Swift); Chippewa Co., Schoolcraft Co. (C. K. Dodge).

2. Vitis-idaea (Tourn.) Hill

(Latin, 'grape of Mount Ida')

Vitis-idaea vitis-idaea (L.) Britton.

Vaccinium vitis-idaea L.

Cowberry; Mountain Cranberry.

Specimen examined. — Isle Royale (A. E. Foote, 1868). Later collectors in Isle Royale have not reported this interesting Arctic species.

3. Polycodium Raf.

(Greek, 'many bells')

Polycodium stamineum (L.) Greene ('with threads,' probably in allusion to the slender pedicels)

Vaccinium stamineum L.

Deerberry; Squaw Huckleberry.

Specimen examined. — Washtenaw Co. (W. Bradfield, 1903, "Ann Arbor;" reported from same county by C. A. Davis).

4. Vaccinium L.

(Latin name)

Flowers solitary or 2–4 together on dropping pedicels.
  Flowers mostly 4-merous .... 1. *V. uliginosum.*
  Flowers mostly 5-merous.
    Leaves obovate or cuneate .... 2. *V. caespitosum.*
    Leaves oval or oblong.
      Leaves serrulate, green .... 3. *V. membranaceum.*
      Leaves entire, pale beneath .... 4. *V. ovalifolium.*
Flowers racemed.
  Fruit blue, with a bloom.
    Tall shrubs of marshes; leaves large .... 5. *V. corymbosum.*
    Low shrubs; leaves small.
      Leaves oblong-lanceolate, green.
        Leaves entire, densely hairy .... 6. *V. canadense.*
        Leaves sharply serrulate, smooth or nearly so
        7. *V. angustifolium.*
      Leaves obovate, pale beneath .... 8. *V. vacillans.*
  Fruit black, without a bloom.
    Low shrub; leaves glaucous beneath .... 9. *V. nigrum.*
    Tall shrub; leaves green ....10. *V. atrococcum.*

1. *Vaccinium uliginosum* L. ('of damp places')
Bog Bilberry; Bog Whortleberry.
Rock shores, and especially around rock pools. An Arctic species, found only locally in the northern part of the state. Not examined by the writer.

Reported from Emmet Co. (C. E. Barr, 1908); Chippewa Co. (Henry Billman); Isle Royale (W. S. Cooper, Henry Billman).

2. *Vaccinium caespitosum* Michx. ('of the turf')
Dwarf Bilberry.
An Arctic species, not examined by the writer.

Reported from Ionia Co. (U. & P. in Beal's catalog); Northern Michigan (*Gray's Manual*).

3. *Vaccinium membranaceum* Dougl. ('membrane-like')
Thin-leaved Bilberry.
Rich woods, in Upper Peninsula only.

Specimens examined. — Chippewa Co. (C. K. Dodge, 1914); Alger Co. (C. K Dodge, 1916); Marquette Co. (A. Dachnowski, 1906); Keweenaw Co. (Mary H. Clark, 1871).

Reported from Schoolcraft Co. (C. K. Dodge).

4. *Vaccinium ovalifolium* J. E. Smith ('oval-leaved')
Tall or Oval-leaved Bilberry.
Rich woods, in Upper Peninsula only.

Specimen examined. — Chippewa Co. (C. K. Dodge, 1917).

Reported from Schoolcraft Co. (C. K. Dodge, 1915, "rich shaded ground, abundant" in both counties).

5. *Vaccinium corymbosum* L. ('flowers in corymbs')
High-bush or Tall Blueberry.
Swamps and bogs, mostly restricted to the Lower Peninsula.

Specimens examined. — Berrien Co. (G. L. Ames, 1868); Cass Co. (F. C. Gates, 1906); St. Joseph Co. (A. B. Burgess, 1903); Van Buren Co. (H. S. Pepoon, 1906); Kalamazoo Co. (F. H. Tuthill, 1874); Calhoun Co. (W. J. Beal, 1898); Washtenaw Co. (M. W. Harrington, 1870); Ingham Co. (C. F. Wheeler, 1893); Oakland Co. (C. Billington, 1915); St. Clair Co. (C. K. Dodge, 1892); Gratiot Co. (C. A. Davis, 1891); Montcalm Co. (C. F. Wheeler, 1900); Newaygo Co. (H. T. Darlington, 1916).

Reported from Wayne Co. (O. A. Farwell); Kent Co. (Emma J. Cole); Huron Co., Tuscola Co. (C. A. Davis); Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); Benzie Co. (W. G. Waterman); Emmet Co. (Fallass & Swift); Keweenaw Co. (O. A. Farwell).

6. *Vaccinium canadense* Kalm. ('of Canada')
Canada Blueberry.
Bogs, dunes and dry forests all over the state.

Specimens examined. — St. Joseph Co. (C. F. Wheeler, 1890); Calhoun Co. (W. J. Beal, 1898); Jackson Co. (C. F. Wheeler, 1892); Ingham Co. (1871); St. Clair Co. (C. K. Dodge, 1904); Muskegon Co. (C. D. McLouth, 1901); Arenac Co. (C. K. Dodge, 1912); Iosco Co. (Beal & Wheeler, 1888); Crawford Co. (1888); Alpena Co. (C. F. Wheeler, 1895); Charlevoix Co. (E. A. Bessey, 1912); Cheboygan Co. (J. H. Ehlers, 1918); Emmet Co. (C. F. Wheeler, 1890); Mackinac Island (C. F. Millspaugh, 1898); Chippewa Co. (C. K. Dodge, 1914); Schoolcraft Co. (C. K. Dodge, 1915); Alger Co. (C. F. Wheeler, 1900); Marquette Co. (B. Barlow, 1901); Gogebic Co. (H. T. Darlington, 1919); Keweenaw Co. (O. A. Farwell, 1886); Isle Royale (A. E. Foote, 1868).

Reported from Magician Lake district (H. S. Pepoon); Oakland Co. (J. W. Stacey); Kent Co. (Emma J. Cole); Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); N. Manitou Island (E. N. Transeau); Beaver Island (H. T. Darlington).

7. *Vaccinium angustifolium* Ait. ('narrow-leaved')
Vaccinium pennsylvanicum Lam.
Low Sweet Blueberry.
All over the state, mostly in dry sandy soil. A pubescent form is noted from Cass, St. Joseph, Ingham, St. Clair and Ontonagon counties. This seems to grade into the regular form.

Specimens examined. — Berrien Co. (G. L. Ames, 1867); Cass Co. (C. F. Wheeler, 1890); St. Joseph Co. (C. F. Wheeler, 1890); Washtenaw Co. (M. W. Harrington, 1868); Wayne Co. (C. Billington, 1915); Oakland Co. (C. Billington, 1914); Ingham Co. (W. J. Beal, 1899); Eaton Co. (L. J. Cole, 1895); Kent Co. (L. J. Cole, 1895); St. Clair Co. (C. K. Dodge, 1892); Gratiot Co. (C. A. Davis, 1890); Muskegon Co. (W. J. Beal, 1898); Lake Co. (W. J. Beal, 1890); Mason Co. (R. W. Chaney, 1910); Iosco Co. (Beal & Wheeler, 1888); Alcona Co. (H. T. Darlington, 1918); Crawford Co. (1888); Grand Traverse Co. (C. F. Wheeler, 1898); Alpena Co. (C. F. Wheeler, 1895);

Cheboygan Co. (J. H. Ehlers, 1918); Emmet Co. (J. H. Ehlers, 1918); Chippewa Co. (C. K. Dodge, 1914); Schoolcraft Co. (C. K. Dodge, 1915); Delta Co. (C. F. Wheeler, 1892); Alger Co. (J. G. Coulter, 1892); Marquette Co. (B. Barlow, 1901); Gogebic Co. (H. T. Darlington, 1919); Ontonagon Co. (H. T. Darlington, 1922); Keweenaw Co. (O. A. Farwell, 1887); Isle Royale (A. E. Foote, 1868).

Reported from Allegan Co. (F. A. Loew); Ionia Co. (H. T. Darlington); Huron Co. (C. A. Davis); Charity Islands (C. K. Dodge); Tuscola Co. (C. A. Davis); Bay Co. to Mackinac Co., Mackinac Island (C. K. Dodge, "common," especially in Arenac and Iosco counties); Manistee Co. (F. P. Daniels); Benzie Co. (W. G. Waterman); Beaver Island (H. T. Darlington); Dickinson Co. (G. H. Coons).

8. *Vaccinium vacillans* Kalm ('swaying to and fro')

Low Blueberry.

Dry woods; restricted to the Lower Peninsula and most abundant in its southern portion.

Specimens examined. — Berrien Co. (G. L. Ames, 1867); Cass Co. (C. F. Wheeler, 1890); Jackson Co. (C. F. Wheeler, 1892); Washtenaw Co. (A. J. Pieters, 1893); Wayne Co. (C. Billington, 1915); Livingston Co. (Wheeler & Longyear, 1898).

Reported from Van Buren Co. (L. H. Bailey); Kent Co. (Emma J. Cole); Gratiot Co. (C. A. Davis); Huron Co. (C. A. Davis); Benzie Co. (W. G. Waterman); Emmet Co. (C. W. Fallass); Cheboygan Co. (F. C. Gates).

9. *Vaccinium nigrum* (Wood) Britton. ('black')

Vaccinium pennsylvanicum nigrum Wood.

Low Black Blueberry.

Sandy ground, especially northward.

Specimens examined. — Huron Co. (C. K. Dodge, 1908); Iosco Co. (C. K. Dodge, 1912); Cheboygan Co. (C. K. Dodge, 1912); Chippewa Co. (C. K. Dodge, 1914); Marquette Co. (C. F. Wheeler, 1892); Ontonagon Co. (H. T. Darlington, 1922); Gogebic Co. (H. T. Darlington, 1919).

Reported from Calhoun Co. (C. E. Barr); Tuscola Co. (C. K. Dodge); Bay Co. to Mackinac Co. along coast (C. K. Dodge, "very abundant"); Osceola Co. (C. F. Wheeler); Emmet Co. (C. E. Barr); Schoolcraft Co. (C. K. Dodge); Keweenaw Co. (O. A. Farwell).

10. *Vaccinium atrococcum* (A. Gray) Heller ('with dark berries') Black High Blueberry.

Bogs, mainly in the southern portion.

Specimens examined. — Cass Co. (C. F. Wheeler, 1890, reported by H. S. Pepoon as about 2 per cent as plentiful as *V. corymbosum*); Van Buren Co. (H. S. Pepoon, 1906); Eaton Co. (H. T. Darlington, 1916); Oakland Co. (B. A. Walpole, 1918); St. Clair Co. (C. K. Dodge, 1904); Montcalm Co. (C. F. Wheeler, 1900); Alger Co. (C. K. Dodge, 1916).

Reported from Kent Co. (Emma J. Cole); Keweenaw Co (O. A. Farwell).

5. Chiogenes Salisb.

(Greek, 'snow-born')

Chiogenes hispidula (L.) T. & G. ('with fine bristles') Creeping Snowberry; Moxie Plum.

Bogs, especially in the northern portion. Not reported from the two southern tiers of counties.

Specimens examined. — Oakland Co. (B. A. Walpole, 1918); St. Clair Co. (1838); Ionia Co. (C. F. Wheeler, 1890); Mason Co. (R. W. Chaney, 1910); Alcona Co. (1888); Crawford Co. (G. H. Hicks); Otsego Co. (E. A. Bessey, 1912); Cheboygan Co. (C. Billington, 1914); Mackinac Co. (C. K. Dodge, 1912); Alger Co. (J. G. Coulter, 1892); Marquette Co. (B. Barlow, 1901); Gogebic Co. (H. T. Darlington, 1919); Keweenaw Co. (O. A. Farwell, 1886).

Reported from Kent Co. (Emma J. Cole); Montcalm Co. (W. J. Beal); Gratiot Co., Tuscola Co., Roscommon Co. (C. A. Davis); shores of Lake Huron, counties unspecified (C. K. Dodge); North Manitou Island (E. N. Transeau);

Emmet Co. (Fallass & Swift); Beaver Island (H. T. Darlington); Chippewa Co., Schoolcraft Co. (C. K. Dodge); Ontonagon Co. (H. T. Darlington); Isle Royale (W. S. Cooper).

6. Oxycoccus (Tourn.) Hill

(Greek, 'sour berry')

Leaves ovate, acute; pedicels terminal, bearing two colored bracts near the middle..1. *O. oxycoccus.*
Leaves oval-oblong, obtuse; pedicels lateral, bearing two leaf-like bracts near the tip..2. *O. macrocarpus.*

1. *Oxycoccus oxycoccus* (L.) MacM.
Vaccinium oxycoccus L.
Small or European Cranberry.
Bogs, all over the state.

Specimens examined. — St. Joseph Co. (C. F. Wheeler, 1890); Washtenaw Co. (H. M. Bailey); Oakland Co. (B. F. Chandler, 1916); Ingham Co. (C. A. Davis, 1892); Kent Co. (L. J. Cole, 1896); Gratiot Co. (C. A. Davis, 1895); Tuscola Co. (C. K. Dodge, 1910); Benzie Co. (1888); Alcona Co. (Bessey & Darlington, 1918); Alpena Co. (Bessey & Darlington, 1918); Cheboygan Co. (J. H. Ehlers, 1917); Emmet Co. (Una M. Hathaway, 1890); Mackinac Co. (C. K. Dodge, 1915); Chippewa Co. (Lewis Foote, 1867); Marquette Co. (Lewis Foote, 1863); Baraga Co. (S. R. Bailey, 1893); Gogebic Co. (H. T. Darlington, 1919); Isle Royale (A. E. Foote, 1868).

Reported from Ionia Co. (C. A. Davis); Bay Co. to Mackinac Co. along coast (C. K. Dodge); N. Manitou Island (E. N. Transeau); Schoolcraft Co. (C. K. Dodge); Dickinson Co. (G. H. Coons).

2. *Oxycoccus macrocarpus* (Ait.) Pursh. ('large-fruited')
Vaccinium macrocarpon (Ait.)
Bogs, all over the state.

Specimens examined. — Berrien Co. (Dodge & Darlington, 1917); Cass Co. (H. S. Pepoon, 1906); Van Buren Co. (H. S. Pepoon, 1916); Washtenaw Co. (M. W. Harrington, 1870);

Ingham Co. (1872); Oakland Co. (C. Billington, 1916); Macomb Co. (B. F. Chandler, 1916); St. Clair Co. (C. K. Dodge, 1893); Gratiot Co. (C. A. Davis, 1895); Charity Islands (C. K. Dodge, 1910); Arenac Co. (C. F. Wheeler, 1900); Mason Co. (R. W. Chaney, 1910); Grand Traverse Co. (D. C. Leach); Alpena Co. (Bessey & Darlington, 1918); Cheboygan Co. (J. H. Ehlers, 1917); Emmet Co. (J. H. Ehlers, 1916); Chippewa Co. (Lewis Foote, 1867); Schoolcraft Co. (C. K. Dodge, 1915); Alger Co. (G. H. Hicks, 1888); Marquette Co. (B. Barlow, 1901); Menominee Co. (J. H. Schuette, 1891); Gogebic Co. (H. T. Darlington, 1919); Keweenaw Co. (O. A. Farwell, 1887).

Reported from Calhoun Co. (C. E. Barr); Kent Co. (Mary J. Fallass); Muskegon Co. (C. D. McLouth); Tuscola Co., Huron Co. (C. A. Davis); Bay Co. to Mackinac Co. along coast (C. K. Dodge); Manistee Co. (F. P. Daniels); Benzie Co. (W. G. Waterman); N. Manitou Island (S. M. Coulter); Beaver Island (H. T. Darlington); Dickinson Co. (G. H. Coons); Isle Royale (W. S. Cooper).

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NOTES ON THE FAILURE OF THE SEED CROP OF *HEVEA BRASILIENSIS* ON THE EAST COAST OF SUMATRA *

CARL D. La RUE

It has for some time been a matter of common knowledge to rubber growers in Sumatra that the Para rubber trees on the East Coast of Sumatra do not produce fruit so abundantly as those in other near-by regions, such as the Federated Malay States and Java. In general the dearth of seeds is not an evil, but is rather a benefit to the rubber producer, since at present there is no market for the seeds and their production inevitably makes large demands on the food resources of the tree. In some localities where large crops of seeds are produced, planters have considered the possibility of stripping the trees of the young fruits to prevent this loss of food. By such persons trees which regularly set only a small number of fruits would be considered very desirable.

To the plant breeder engaged in selection of the rubber tree, however, the failure of seed crops is a more serious matter. It is extremely discouraging to find that many trees which produce high yields of rubber bear few seeds, or none, and it is exasperating, to say the least, to find that pollinations made in the hottest part of the day, and from the top of a ladder, result in the setting of no seeds whatever. After encountering such obstacles to progress in selection and hybridization, the author began to make such inquiries into the cause of the failure of

* The work reported in this paper was done in 1919 on the plantations of the Hollandsch-Amerikaansche Plantage Maatschappij, Kisaran, Asahan, Sumatra. This paper is published with the approval of the U. S. Rubber Plantations, Inc., of New York.

the seed crop as he could, although the pressure of other work prevented any continuous or extensive investigation. The data gained in this unfinished study are given here in the hope that they may be of value to other workers on this interesting tree.

In October, 1919, when he visited Java, the author first had an opportunity to contrast seed production of Hevea in Sumatra with that in parts of Java. In the latter regions a number of fruits are usually borne on each peduncle, so that the cluster of fruits bears a rough resemblance to a bunch of grapes. On Pasir Waringin Estate in Banta in West Java as many as fifteen fruits have been seen on a single peduncle. In Sumatra the inflorescences commonly set only a few fruits, one or two being the usual number, while more than four fruits on a single peduncle are very rarely found. Each fruit normally contains three seeds,[1] so that the number of seeds resulting from any inflorescence is small, while the majority of the inflorescences produce no seeds at all.

ABNORMAL ABSCISSION OF FLOWERS AND FRUITS

The flowers of Hevea are monoecious, as has been reported by Maas.[2] The staminate flowers are produced in large numbers, while the pistillate ones are comparatively few in each inflorescence. By field observations the author found that in Sumatra the larger number of the staminate flowers often fall before anthesis. The percentage of female flowers which fall before fertilization is much smaller, but many more fall immediately following the flowering. It is possible that these latter may fall because they were not fertilized, but this seems unlikely, since an abundance of good pollen is produced by uninfected staminate flowers.

The young fruits grow rapidly, but a large percentage drop from the trees during the first six weeks of their development.

[1] La Rue, Carl D. *Variation in Fruits and Seeds of Hevea. Verslag van de achtste bijeenkomst van het technisch personeel der proefstations*, etc. Medan, Deli. Sumatra, 1919.

[2] Maas, J. G. J. A. *De bloembiologie van Hevea brasiliensis. Archief voor de Rubbercultuur*, 3: 288–307. 1919.

As they become larger, fewer of them fall, but there is a continuous, though decreasing, loss until the fruits are mature.

When fruits which have recently fallen are examined, they are generally found to be quite firm and green without discoloration. The pedicels, however, which usually fall with the fruit, are frequently discolored and somewhat withered, especially near the point of abscission. Fruits which have been lying on the ground for a short time show dark, rotten spots, which usually bear masses of the pink spores of *Gloeosporium alborubrum* Petch. Later these fruits become rotten throughout, and are almost completely covered with Gloeosporium spores.

ATTEMPTS TO ISOLATE THE CAUSAL ORGANISM

Studies made by La Rue and Bartlett [3] previous to this investigation indicated that the organism which caused an abnormal leaf-fall of Hevea on the East Coast of Sumatra was also capable of causing an abscission of young fruits. The field observations noted above, which were made over considerable areas for a period of more than a year, increased the suspicion that *Gloeosporium alborubrum* was the principal cause of the abnormal falling of unopened flowers and of young fruits. Experiments were now made to determine the truth or falsity of this suspicion.

Experiment I. — On March 24, 1919, very young fruits which had fallen from the trees were carefully washed with Hg Cl 1/500, rinsed in sterile water, and put into sterile tubes of Hevea agar.[4] Within two weeks all of the twelve tubes containing the fruits had developed *Gloeosporium alborubrum.* All contained masses of the pink spores of the fungus. (In all of the cultures made in this investigation the presence of the spores was the only criterion used for the determination of the presence of Gloeosporium. In some cultures a mycelium like that of Gloeo-

[3] La Rue, Carl D. and Bartlett, H. H. *A Leaf-fall Disease of Hevea brasiliensis Muell.-Arg. due to Gloeosporium alborubrum Petch. Papers of the Michigan Academy of Science, Arts and Letters,* 2: 73–90. 1922.

[4] La Rue, Carl D. and Bartlett, H. H., *Loc. cit.*

sporium appeared, but where no spores developed this was considered the mycelium of an "undetermined fungus.")

Experiment II. — A number of inflorescences were collected on April 19. Material from these was sterilized as in Experiment I and put into tubes of Hevea agar as follows:

Female flowers, some opened, some not yet opened	12 tubes
Peduncles of inflorescences from which some flowers had fallen	12 tubes
Pedicels of male flowers	12 tubes

All of these cultures developed *Gloeosporium alborubrum* uncontaminated by any other fungus or by bacteria.

Experiment III. — On May 6, 1919, young fruits which had fallen from the trees were collected, and those which were still green and unrotted were separated from their peduncles, treated as in Experiment I, and put into sterile tubes of Hevea agar. A number of green, apparently healthy, fruits were plucked, and the pedicels were removed from these, sterilized and put into agar tubes. Several of the fruits which had fallen to the ground were sterilized, rinsed and put into moist chambers. The whole number of cultures was:

Tubes containing fallen fruits	24
Tubes containing pedicels of fallen fruits	24
Tubes containing pedicels of plucked fruits	12
Moist chambers containing fallen fruits	17

Within three days sixteen of the twenty-four tubes containing pedicels of fallen fruits produced Gloeosporium spores. This set of tubes ultimately gave these results:

Gloeosporium alborubrum	15 tubes
Gloeosporium alborubrum and unidentified fungi	4 tubes
Undetermined fungi	5 tubes

The fallen fruits in agar tubes with one exception gave rise to growths of fungi as shown below:

Gloeosporium alborubrum only	6 tubes
G. alborubrum and unidentified fungi	11 tubes
Fusarium sp.	3 tubes
Diplodia cacaoicola	1 tube
Unidentified fungi	2 tubes
Sterile	1 tube

The tubes containing pedicels of plucked, apparently healthy fruits showed the following developments:

Gloeosporium alborubrum	1 tube
G. alborubrum and an undetermined fungus with a dark mycelium	4 tubes
Undetermined fungus with a dark mycelium	7 tubes

All of the fallen fruits in moist chambers, seventeen in all, developed *Gloeosporium alborubrum.* Most of them also showed bacteria and other fungi.

Experiment IV. — On May 8, 1919, fallen fruits were collected, sterilized as in the other experiments, and put into tubes with Hevea agar as follows:

Fallen fruits	12 tubes
Pedicels of fallen fruits	12 tubes

These cultures resulted thus:

Cultures of fallen fruits:

Gloeosporium alborubrum	7 tubes
G. alborubrum and *Diplodia cacaoicola*	1 tube
Diplodia cacaoicola	2 tubes
Unidentified fungi	2 tubes

Cultures of Pedicels:

Gloeosporium alborubrum	5 tubes
G. alborubrum and an unidentified fungus	5 tubes
Diplodia cacaoicola and unidentified fungus	2 tubes

From fruits which had fallen and from inflorescences apparently diseased 113 cultures were made. Of these 75 contained *Gloeosporium alborubrum,* 6 contained *Diplodia cacaoicola,* 3 con-

tained *Fusarium sp.*, 31 contained fungi of some three or four sorts which did not fruit, and 1 was sterile. Of the unidentified fungi there were several cultures of what looked like *Helminthosporium Heveae* Petch. *Gloeosporium alborubrum* was the only fungus which was isolated from any considerable number of the cultures, and consequently the idea that it might be the causal organism of the fruit-fall was strengthened to a considerable degree.

Of the thirty-six cultures made from apparently healthy material, twenty-nine contained *Gloeosporium alborubrum*, and eleven contained an undetermined fungus with a dark mycelium which was probably *Helminthosporium Heveae.* Though it is apparent that Gloeosporium was isolated from a larger percentage of what was taken to be healthy material than from the diseased parts of the trees, this does not entirely vitiate the results of the former cultures. La Rue and Bartlett found in their work on leaf-fall of Hevea already cited, that most of the trees over large areas contained the fungus in their tissues. It is not surprising, therefore, that it develops in cultures of apparently normal fruits; but under such conditions it is impossible to secure absolute proof that the abscission of fruits is due to this fungus. The cultures serve to show that no other fungus is commonly present in diseased fruits, and that, if the disease is attributed to any organism, the blame must fall on *Gloeosporium alborubrum.*

INOCULATION TRIALS

On May 6, 1919, healthy young fruits were plucked from the trees, sterilized, and put into sterile moist chambers. Thirteen fruits were used of which six were kept as controls, and seven were inoculated by pricking them with a needle dipped in a suspension of spores from a pure culture of *Gloeosporium alborubrum.* In six days five of the seven inoculated fruits had produced extensive growths of this fungus with masses of spores. On three of the controls there were slight growths of Gloeosporium on the pedicels. Ultimately all of the fruits, both

inoculated and uninoculated, produced Gloeosporium, but the inoculated fruits developed the infection most rapidly and extensively. This result is identical with those obtained by La Rue and Bartlett with inoculations of twigs. There is no doubt that the fungus is capable of causing a destructive rot of the fruits, but, in the field, abscission of fruits usually occurs before this rot has developed. It is worthy of note that in this region the outer, rather soft part of the wall of the ripening fruit is very frequently rotten and covered with a mass of Gloeosporium spores.

Further studies of this disease should be made on plants entirely free of Gloeosporium, and microscopical investigations of the pedicels should be made to determine the nature of the abscission. The author made fixations of material for this purpose, but has been unable to section and study the material. Although it is probable that other factors play a part in the formation of a group of conditions unfavorable to fruit production, the author believes the evidence presented sufficient for ascribing, for the present at least, the major part of the injury to *Gloeosporium alborubrum*.

CHARACTERISTICS OF THE FUNGUS

The identity, cultural characteristics, etc., of *Gloeosporium alborubrum* Petch have been described in some detail by La Rue and Bartlett in their work on the Gloeosporium leaf-fall disease. As no further work of this kind was done in connection with this paper, discussion of details of the fungus would lead to repetition.

INFECTION

Since both in this investigation and in that of the leaf-fall disease, it has been found that Gloeosporium is present in apparently normal tissue of the twigs, inflorescences, etc., it appears that the fungus may grow out from the twigs into the peduncles and to the pedicels. The abscission of the pedicels bearing flowers or fruits follows if conditions are favorable, just as an

abscission of young leaves may occur earlier in the season. It is possible that some flowers of an inflorescence may be inoculated by insects, and that the infection may spread throughout the inflorescence, causing the abscission of other flowers and later of fruits. It is unlikely that the ovaries, which fall after they have developed into young fruits, are inoculated by insects at the time of pollination, because it is the pedicel which first shows signs of injury. This may be much discolored when abscission takes place, while the fruit is generally quite green and without signs of injury at this time.

METHODS OF PREVENTION

No promising method of prevention of the disease can be suggested at the present time. It is only rarely that the production of seeds becomes a matter of economic importance. In selection work, where the seeds are most valuable, only a relatively small number of trees are concerned, and these are widely scattered. If inflorescences are infected externally during development, this infection might be prevented by spraying with some fungicide. Spraying would, of course, be possible only in readily accessible areas, such as special seed gardens. Where high-yielding trees are scattered over a large estate, it would hardly be expedient to spray them in an attempt to increase the seed production.

The methods suggested for combating the leaf-fall disease, cultivation and fertilization to increase the vigor of the trees, may be of some value, but are less likely to be successful in the treatment of fruit-fall. The latter affection is by no means so strictly limited to areas in which the trees lack vigor as is the former. While trees in poor condition, as evidenced by poor leaf color, die-back, and infection by *Cephaleuros virescens*,[5] are generally affected, trees in very vigorous condition do not escape, and it is only in regions from which the leaf-fall disease due to *Gloeosporium alborubrum* has not been reported that the trees

[5] La Rue, Carl D. *Two Unreported Parasites of Hevea brasiliensis. Papers of the Michigan Academy of Science, Arts and Letters*, 2: 69–71. 1922.

bear a full crop of seeds. Accordingly, so far as possible, experimental gardens for breeding work should be located in the latter areas.

SUMMARY AND CONCLUSIONS

1. The Para rubber trees on the East Coast of Sumatra usually fail to bear as large crops of seeds as those in the Federated Malay States and in Java.
2. A light seed-crop may be an advantage, since it makes smaller demands on the trees, but in breeding work, the small number of seeds produced may be a serious obstacle to progress.
3. Cultural studies show *Gloeosporium alborubrum* Petch to be constantly associated with the phenomena of fruit- and flower-fall.
4. Conclusive inoculation tests have not been made, because *Gloeosporium alborubrum* exists in a dormant condition in many trees, and it is difficult to secure plants certainly free from it. It has been shown, however, that this fungus may cause a rapid and destructive rot of young fruits.
5. The fungus appears to grow out from the twigs, where it is apparently dormant, into the inflorescences, causing abscission of flowers and later of fruits. Primary infection of parts of the inflorescences may also occur.
6. Primary infection of inflorescences might be controlled by spraying, which would be feasible only in experimental gardens. Control of the invasion of the inflorescences by hyphae from the twig is undoubtedly more difficult. Improvement of the vigor of the trees by fertilization and cultivation might be effective in some cases, but not in all, since the disease occurs on trees in full vigor. Only those areas free from Gloeosporium leaf-fall disease produce full crops of seed.
7. Experimental gardens for work in breeding the Para rubber tree should be located, if possible, in regions which are not subject to the Gloeosporium leaf-fall disease.

University of Michigan

OPTIMUM TEMPERATURES FOR GROWTH OF SOME GRASS COLEOPTILES

F. C. NEWCOMBE

In studying some phases of the heliotropic behavior of some plants, it became necessary to know the relation of growth to temperature. Although Nybergh (1) claimed that the presentation time for geotropic response was not affected by the temperature at the time of stimulation, Miss de Vries' work (2) shows that the presentation time for *Avena sativa* coleoptile shortens with increasing temperature up to about the optimum, above which the presentation time lengthens.

A search of botanical literature revealed determinations of optimum temperatures for the roots of several plants, and for several species of seedlings in which the growth of the whole seedling was measured. A summary of some of this work may be found in Pfeffer's *Pflanzenphysiologie.* But the optimum temperatures for the growth of the coleoptiles of grasses were not found in literature. Incidentally to my study of heliotropism, the approximate optimum temperatures for growth of the coleoptiles of ten species of grasses and of the hypocotyl of four species of dicotyledons were determined. The summarized results are to be found in the table accompanying this paper.

METHODS

Since the object of the study was to learn the growth rates of the coleoptile in different temperatures, the seedlings were raised in pots of garden earth, the pots being about 10 cm. in diameter. As is well known, the rate of growth of plants varies for different members, for the same member at different ages, and for the same member in different environments. Efforts to

measure the growth were, therefore, confined to the coleoptile, from the time when this member appeared above ground to a time preceding the appearance of the first leaf. This period, in the high temperatures used, was from twenty-four to forty-eight hours long. A homogeneous, friable, garden earth was used, which was well mixed and passed through a sieve before planting the seed. Anyone who has raised grass seedlings in earth knows how sensitive they are to differences of moisture in the soil. Special attention had to be given constantly to maintaining an equable amount of water in the various pots of a series.

The seed used was obtained from commercial seedsmen, and none of the grasses showed a high degree of germination; some samples from the most reputable firms gave no germination at all, notwithstanding that various approved methods, such as alternating warmer and colder temperature, were employed. However, the alternating temperature method, as lately published by Harrington (3), was noticeably effective in promoting germination of *Poa pratensis* L. and *Dactylis glomerata* L. The seedlings began appearing above the soil in five to six days after planting; the grains had been buried to a uniform depth of about 5 mm., though the larger ones, like those of Sorghum and Phalaris, were buried a little deeper.

The work on heliotropism, which was to follow the present preliminary study, requiring that each pot of seedlings have a separate, opaque cover, the seedlings here used were grown in the dark, and, before they had emerged from the ground, their containing pots were covered with small metal cylinders, closed at the upper ends, while the lower ends of the cylinders were pressed into a little earth filling the saucers in which the pots stood. The seedlings, therefore, were not only in the dark, but they were in a very moist atmosphere as well.

When the seedlings were observed to be emerging from the ground, the containing pots with their covers were placed in the constant temperature incubators, there to assume the respective temperatures desired. Preceding tests had shown that, for the size of pots used, about four hours were sufficient to bring the

TABLE SHOWING OPTIMUM TEMPERATURES FOR ELEVEN COLEOPTILES AND FOUR HYPOCOTYLS

Species	No. of Series	No. of Plants	Average Opt. Temp.	Representative series to show relative growths in 12 hours					
				26°	28°	30°	32°	34°	36° C.
Sorghum vulgare L.	3	252	31° C.	....	15.6mm.	23.4mm.	20.9mm.	21.1mm.	19.8mm.
Setaria Italica (L.) Beauv.	3	172	33	....	16.5	21.6	25.2	26.0	22.0
Setaria Italica var. Germanica (Mill.) Richter	5	395	33	....	18.0	23.6	27.0	30.8	26.6
Phalaris canariensis L.	6	324	30	10.2	11.8	12.6	11.0	5.7	5.0
Phleum pratense L.	6	633	30	4.9	6.3	6.3	5.5	4.0	3.3
Agrostis alba L. var. vulgaris (With.) Thurb.	5	794	29	2.8	4.0	3.9	3.3	3.2	
Dactylis glomerata L.	5	327	29	7.9	5.9	8.8	7.4	6.1	1.7
Poa pratensis L.	6	591	27	4.2	4.9	3.7	3.2	2.1	1.6
Lolium perenne L.	8	470	30	5.0	5.4	6.6	5.1	4.5	
Avena sativa L.	3	401	30	....	16.2	17.2	13.7	9.3	
Triticum sativum L.	3	167	30	16.5	18.0	20.3	18.3	14.2	
Lepidium sativum L.	3	227	29	5.0	5.3	6.9	5.4		
Brassica Napus L.	3	210	31	21.5	22.2	22.7	23.3	21.4	
Amaranthus Gangeticus L. (Melancholicus ruber)	4	267	33	9.8	19.3	19.3	23.2	24.6	18.6
Papaver somniferum L. (paeoniaeflorum)	5	229	27°	24° 4.7 / 26° 6.5	5.9	5.4	4.5	5.0	3.2

preparations to the experimental temperatures. This preparatory period before the first measurement was never less than four hours, and it was usually ten to twelve hours. The tests were run in series. A series consisted of one species of plant with one pot in each of the temperatures 24° C., 26°, 28°, 30°, 32°, 34°, and 36°. For special purposes, a few series included fewer and a few series more temperatures than those mentioned. The period for measured growth ranged from six to seventeen hours; but, for most of the series, the period was from eight to twelve hours. In the accompanying table, all growths have been reduced to the twelve-hour period for ease in comparison. For measuring the seedlings of one pot — usually 10 to 25 seedlings — a period of one to three minutes was required. An assistant recorded the measurements as the author called them off. The seedlings were out of the incubators and out of their moist chambers while the measurements were made; but the one to three minutes taken could hardly have vitiated the result at the second measurement, seeing that the period of growth between the two measurements was so long.

The measurements were made with naked eye, by the use of a white celluloid ruler graduated in millimeters. This ruler, which was cut from a larger one, was 4 mm. wide and 10 cm. long. To one end of the little ruler was cemented a flat plate of celluloid, $2\frac{1}{2} \times 4$ millimeters. The broad surface of the little plate was perpendicular to the long axis of the ruler. This little instrument was used to tamp down gently the earth if it was uneven about the individual seedlings, and thus the accuracy of measurement was increased. At first, no attempt was made to read to greater accuracy than to the millimeter marks. After some practice, it was found easily possible to read to the half millimeter. With the cemented foot of the ruler resting on the ground, the height of the tip of each seedling was called off by naming the millimeter mark, or the half between two marks nearest which the tip of the seedling showed. If the measuring is carefully done, and the earth about the seedlings firm so that the measuring ruler does not sink into the earth, one should be able to measure accurately to less than one-fourth millimeter.

In order to test the degree of accuracy of measurement, or at least the constancy of measurement, the seedlings of six pots were re-measured within a few minutes of the preceding measurement, the seedlings of several pots having been measured in between, so that the memory did not hold over. A pot with 30 seedlings gave in the first measurement a total of 153 mm., in the second measurement 159 mm.; a second pot with 26 seedlings gave in the two measurements 248.5 and 250.5 mm.; a third pot with 34 seedlings gave 276 and 272 mm. These are differences of 4 per cent, 0.8 of one per cent, and 1.5 per cent respectively. Three measurements of other pots at another time with 18, 22, and 31 seedlings gave variations of 0.7 of one per cent, 4.3 per cent, and 1 per cent respectively. The variations of 4 and 4.3 per cent were made with *Poa pratensis*, one of the grasses with the shortest seedlings, the seedlings of the two pots averaging, when the measurements were made, 6.4 and 5.1 mm. respectively.

One may ask whether the microscopic method of measuring growth would not lead to more accurate results. There can be no question that in practice the microscopic method would be far less accurate with the grasses. In the same pot of seedlings, during the twelve-hour period of growth, one frequently finds variations of growth extending from a minimum of 5 mm. to a maximum of 25 mm. If 30° is accepted as the optimum temperature for growth, there will always be several seedlings in pots kept at higher temperatures, and in pots kept at lower temperatures, which make greater growth than several in the pot in optimum temperature, the group averaging the greatest growth. To think of bringing enough seedlings under microscopic observation to overcome the effect of this individual variation, and the effect of changes in individual rates of growth during the experiment, is quite impossible. There would seem to be little likelihood of large error in determining the optimum temperature for seedlings making a growth of 7 mm. or more between the two measurements. Even for the shorter and more slowly growing seedlings, such as those of *Poa pratensis* and *Agrostis alba*, likelihood of error would be reduced by increased number

of seedlings; and it will be noted by reference to the table that for the more slowly growing seedlings a very large number of seedlings was used. If the error in measurement for the shorter seedlings falls below 5 per cent, as indicated above, a difference of growth of .2 mm. in the sequence of a series showing but 5 mm. growth would not be significant; but a difference of .3 mm. or more in two temperatures of a series might be relied on as showing an average difference in the rate of growth.

DISCUSSION OF RESULTS

When one measures the growth of seedlings in different series put through the same grades of temperatures, it is more or less disturbing, but nevertheless inevitable, that he should find the rates of growth varying from series to series; and this in spite of the fact that allowance has been made for personal errors. It is the inevitable consequent of biological experimentation, due to the practical impossibility of controlling completely the external and the internal conditions for the activity of organisms. For instance, in the five series of seedlings of *Agrostis alba* used in the present experiments, averaging over 150 seedlings for each series, the optimum temperature for growth fell once in 26°, once in 28°, and three times in 30°. As the average difference in growth at these three temperatures was not, however, more than .1 mm., it is not certain that these differences were not due to the limitations of the method of measurement used. But with *Avena sativa* the differences recorded were too great to be ascribed to errors of measurement; yet here, the optimum temperature fell once in 28°, once in 30°, and the third time in 32°. Unexplained variations in the rate of growth are not uncommon, as illustrated also by the work of Koeppen as given by Pfeffer (4) for the growth of the seedling of *Pisum sativum*, which shows in temperatures rising from 10.4° to 36.5° a curve not smooth, as might be expected, but undulating with five crests.

With the different series of a species showing average results unlike for optimum temperature, how shall one make use of all

the series of a species to aid in determining the optimum temperature? One might add together all the growths at the same temperature in the different series of the same species, and thus obtain a series of averages. But unless the number of seedlings were the same at each temperature in all the series of the species, the result might be far from expressing the truth. A better way of combining the series of a species is to average the optimum temperatures of all the series. Thus, for *Avena sativa*, the three series gave the three optima, 28°, 30°, and 32°. The average of these would be 30°, and it is so set down in the table. The five series with Dactylis gave optima of 28°, 28°, 28°, 30°, and 32°; these make an average of 29°, as found in the table, though there were no tests at 29°.

The table shows no temperatures employed below 26°, though, for the most of the species, 24° was used also. The growths in this temperature were always less than in 26°, and hence, to save space, the records of growths at 24° are omitted. For some series, other temperatures besides those recorded were employed; but they add little to the result. By using temperatures two degrees apart, the results suffer in attempted accuracy; for if the record shows in a series the greatest growth at 30°, it might be that there was still greater growth at 29° or at 31°. Of course, the measured growths at the temperatures above the 30° compared with that next below would give some inkling as to whether the optimum was likely to lie above or below the 30° place. The method of averaging the optima of the series would also help in fixing the average optimum to a certain temperature degree.

In the table, the last six columns are intended only as illustrations of representative series for the various species. It will be observed that the optima as given in these representative series do not in all cases coincide exactly with the average optima as given in the third column. It was from such series as those given in the table that the average optima were derived. It is worth noting that the optimum for the coleoptile of the most of the grasses as well as for the hypocotyl of three of the four dicotyledons lies near 30°. It would not be remarkable, if

a more painstaking research should show that for both of these species, namely, *Poa pratensis* and *Papaver paeoniflorum*, seeing the growth for measuring is so small, the optimum should be other than 27°.

University of Michigan

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A COMPARATIVE STUDY OF THE DISTRIBUTION OF THE CLIMAX ASSOCIATION IN SOUTHERN MICHIGAN

B. E. QUICK

I. Introduction

During the 1911 season of the University of Michigan Biological Station on Douglas Lake in Cheboygan County, Michigan, many differences were noted between the beech and maple forests of this region and those of the southern part of the State. The presence of different species of dominant trees in these woods as compared with those farther south, as well as the differences in the herbaceous vegetation, suggested the advisability of making comparative studies of beech and maple woods throughout the Lower Peninsula of Michigan in order to determine whether the differences were sufficient to classify as distinct types these forests which had possibly entered the State by different routes, or whether they might be part of the same vegetative type differing merely in certain climatically limited species. The soil requirements seemed also of interest, as this kind of forest occurs in the north on light soils, while in the south, especially near Ann Arbor, it is found on heavier soils.

During the academic year of 1912–1913 and the summers of 1912, 1913, and 1914 investigations were made under the direction of Dr. H. A. Gleason, of the University of Michigan. To him I am indebted for his kindly interest and many valuable suggestions, as well as for access to some notes taken in travelling about the State. I am also indebted to Professor F. C. Newcombe for many useful suggestions and criticisms.

Species lists, habitat and soil notes, as regards not only the original condition, but also the degree of modification of the

same by plant growth and counts of the trees present for percentage of abundance of the dominant plants were made for all of the stations studied; quadrat studies were made in many cases also. Notes made from trains in going from one part of the State to another were found, when verified by data taken on foot over the same areas, to be of value in studying the soil preferences as well as the general distribution of many of the larger species of plants.

The nomenclature used throughout is that of the seventh edition of Gray's *Manual of Botany*, so no other authorities will need to be cited for the individual plant names. The herbarium at Michigan Agricultural College, as well as the one at Ann Arbor, was consulted in reference to the identity and distribution of several plant species.

The illustrations are all from photographs made, developed and printed by the author.

II. General Considerations

A. Climate

The climatic character of the southern part of Michigan can well be expressed by the following figures. The three cities selected for the graphs in Figures 4 and 5 were chosen because they showed extreme variation in the climatic factors, and also because they were located at wide distances from one another. Alpena is located on Lake Huron near the northern end of the peninsula; Port Huron is on the same side of the State, but farther south, below the "Thumb" region, while St. Joseph is on Lake Michigan near the southwest corner of the State. The data used in the curves were gathered from the United States Weather Bureau report for 1912, and represent the averages of twenty to thirty years of observation. The mean temperatures vary similarly in the three places; the mean temperature for the entire Lower Peninsula is close to that for Port Huron. The maximum and minimum temperatures are strikingly close together in range and in values, both being less extreme than those given for northern Illinois by Gleason (1910). Mean tempera-

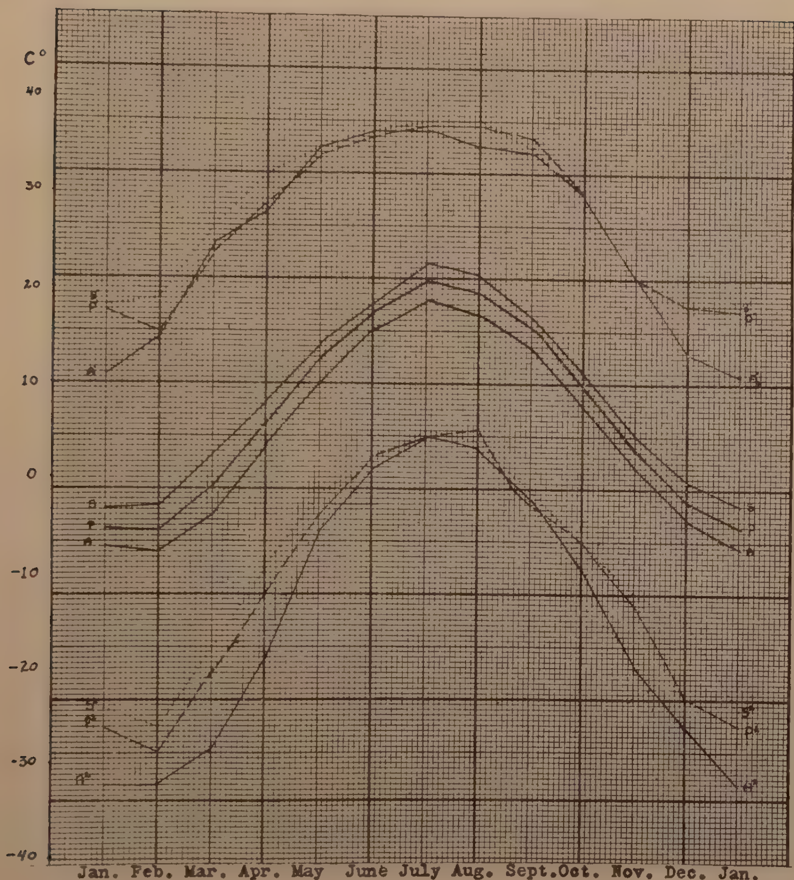

FIG. 4. Temperature Curves for Alpena, Port Huron and St. Joseph. A, P and S, mean temperatures from January to January; A′, P′ and S′, maxima; A^2, P^2, and S^2, minima.

Constructed from records published in U.S. Dept. Agric. Weather Bureau Bull., sections 62 and 63, 1907.

tures seem related to latitude; maxima, to neither latitude nor the nearness of the lakes; minima, to latitude, but in a very irregular manner.

For the Lower Peninsula the average latest killing spring

frost occurs about May 10, and the earliest in the fall about October 4, so the growing season averages about 140 days. Alpena has an average growing season of 135 days, Port Huron of 154 days, and St. Joseph of 177 days. The length of the growing season is generally dependent on the latitude, but is also influenced by the nearness of the Great Lakes, especially Lake Michigan. The winds come from a generally western direction, and, sweeping across this lake, they give up in summer or take up in winter a considerable amount of heat, which greatly moderates their effect. This is best demonstrated by the

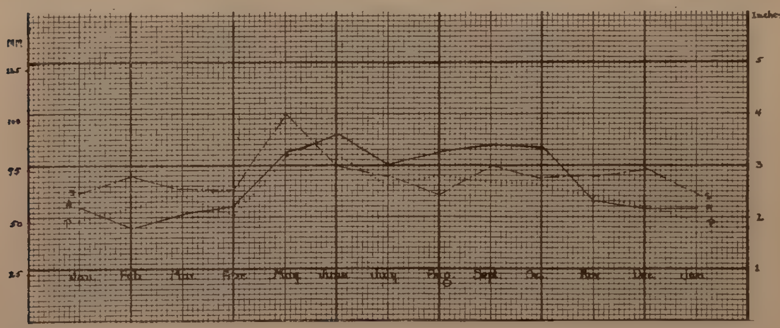

FIG. 5. Chart of Rainfall. Expressed in millimeters to the left and in inches to the right. A = Alpena, P = Port Huron, S = St. Joseph.

Constructed from records published in U.S. Dept. Agric. Weather Bureau Bull., sections 62 and 63, 1907.

results in an area of moderate temperatures called the "fruit belt," which lies along the western side of the State parallel to the lake.

Past students of the climatic conditions have divided this region into different climatic zones. Transeau (1905) mapped areas of "relation of rainfall to evaporation," three of which entered the Lower Peninsula of Michigan. Livingston (1911) divided the State into three zones, at right angles to Transeau's, in mapping areas of like evaporation, and later (Livingston and Livingston, 1913) made maps of temperature summations and also of "temperature efficiencies," in both of which the zones resembled those of Transeau in a general way. As was shown

by Brockmann-Jerosch (1913), single characters of any sort are insufficient for demarking plant zones; and, in general, meteorological conditions are of little value in explaining differences in vegetation for the smaller regions, although they may be significant for the larger ones.

B. GEOLOGICAL HISTORY

The geological history of Michigan is of interest in two ways: first, because it determined the nature of the soils, and, second, because it directly controlled the time of entry, as well as the order and place of entry of the present flora.

At the time of the glacial period some 15,000 to 50,000 years ago, the great ice-sheet covered Michigan and extended as far south as the valley of the Ohio River. After several retreats and re-advances, the final retreat of the ice left the State with its former rock masses planed down, its former valleys filled, and its surface covered with a general mantle of rock-débris and drift which varied in thickness. The soils thus derived are various in character, as well as in origin: some are clays, sands, or gravels left as moraines by the gradual melting of nearly stable ice-margins; some are deposits in the beds of glacial streams with variations in coarseness depending on the rate of flow in the streams at the time of deposition; still others are fine sands or gravels laid down in ancient lake-beds.

C. ORIGIN OF THE FLORA

During the farthest advance of the ice-sheet the entire State was covered with a deep layer of ice, so that all previous vegetation was completely destroyed. These ice-masses persisted for a long enough time to sterilize the soil completely, at least as regards the higher plants, so that on the retreat of the ice no plants or plant parts remained alive, and large areas of bare soil were left exposed. Geological studies have shown that the ice-margin was not that of a single sheet, but that several retreats and re-advances were separated by periods of temperate

climate which left vestiges in the form of plant remains between the layers of glacial soil. Following the last retreat of the ice, boreal plants occupied the soils growing close to the ice-margins on the higher areas not submerged in the glacial lakes as tundras and bog-associations.[1] Then came conifers on the east and west, and finally deciduous trees advanced from the south to replace the conifers. The conifers were not present in the Ohio Valley, so that the deciduous trees and shrubs directly replaced the tundra and bog-associations in the south central part of the State (Transeau, 1903).

While deciduous forests entered from the southeast, prairies entered from the southwest, being later almost entirely replaced by the deciduous trees. The advances of forest and prairie were not simultaneous, but they alternated in waves, due either to alternating moist and dry periods, as was shown for Scandinavia by Blytt (1881), or to warm and cold periods (Hay, 1910), which would bring about the same effect by increasing or decreasing the evaporation with unchanged precipitation. The general tendency today seems toward a more moist climate (Knowlton, 1910), and this is shown by the present advance of forest on prairie as well as by the advance of deciduous forest upon coniferous forest.

D. THE UNITS OF VEGETATION

The Formation

Although plants have been discussed from the time of Humboldt in regard to their relations to one another in the natural groupings in which they are found, there has always been some disagreement as to the names for these natural groups. The larger divisions of vegetation were given a name in 1838 by Grisebach (Warming, 1909) when he spoke of a "formation" as "a group of plants which have a decided physiognomic character, as a meadow, forest, etc." A recent use of the term formation is that of Nichols (1917), who defines it as "an asso-

[1] Adams, 1902; 1905 B; Cowles, 1911; Harshberger, 1904 A, 1905; and Scharff, 1912.

ciation-complex which is related to a specific physiographic unit area," in which the "association-complex" includes the idea of a successive series of plant groups, quite possibly of different physiognomic character. It is more in keeping with the original idea of the term to define it as follows: A *formation* is a group of plants of the same physiognomic character which dominates a large region or province as its characteristic vegetation. An example of this would be the *deciduous forest formation* which dominates the Northeastern Deciduous Forest Province, and would include all of the deciduous forests of the region, whether they have or have not successional relations to one another.

The Association

The association is a more restricted group of plants, subordinate to the formation. Humboldt first used this term in 1807 (Warming, *l.c.*). Warming calls the association "a floristic species of a formation which is an oecological genus." Nichols (1917) defines it as "any group or community of plants which occupies a common habitat" and also "any stage in a given successional series." In this paper the term *association* will be used as a natural group of plants whose interrelations and individual peculiarities enable them to live together as a homogeneous community of definite biotic composition. The definiteness of the habitat has been disregarded here, for the character of the association depends more on the forms associated together in it, and on how they associate, than upon the environment where it happens to have developed.

In any association certain forms dominate either by their size, abundance, or effect on the environment, and so are called *dominants*. These dominants may be either a single species or several species in any association, and in the latter case may be present in different proportions in the different *consocies* (Gleason, *l.c.*) of the association. Certain dominants are usually common to two or more such consocies, and the secondary plants are often entirely the same; in other cases the dominants will be alike and the variation will occur in the secondary plants. An

association is thus seen to be a variable, and to vary about a mean in the same way that a species does.

The Climax Association

Besides the fluctuating changes in the association mentioned above, the association is also constantly changing in a definite direction. Each association changes the conditions of light, soil and water for the habitat which it occupies, and these changes make possible the entry of plants able to endure the changed conditions. The entry of these invaders may mean the replacement of the pioneer association, especially if the seedlings of the pioneers are intolerant of shade. Such successions occur repeatedly until an association develops which is not merely able to endure conditions as it finds them, but to perpetuate these conditions, and so live undisturbed unless the balance is upset by climatic change, or by destruction by a cataclysm. Such an end member of a series of successive associations is called a *climax association.*

Whatever the nature of the initial conditions in a region, whether hydrophytic or xerophytic, there is a modification of them in a mesophytic direction. When the conditions are finally established, the vegetation has also arrived at the corresponding condition, and we have the climax association occupying the region in all of its thoroughly matured areas. The nature of the climax association is therefore mesophytic (Fuller. 1914).

For any of the provinces of North America so far delimited, there does not seem to be a definite climax association, i.e., one which can be called the climax for the entire province; there is, however, a tendency in that direction. For smaller areas the climax can often be positively identified, or even predicted from comparisons with similar areas. When two provinces are in contact, there is a struggle for supremacy between the various associations of both, and the climax will be now that of one province, now that of the other, depending on the conditions of soil, water, and topography. It is readily seen that with base-leveling, humus formation, and the consequent increasing mesophytism of the environments, the more

mesophytic climax association will ultimately survive in such a region. Thus there is an advance of one province upon the other, so we may be able to predict a *climax formation* which will ultimately dominate all of the land surface as far as climatic conditions will allow.

In the deciduous forest province of North America the dominant formation is deciduous forest, and all of the associations of this province are tending toward a certain formation which is represented in the smaller areas by the several higher members of the successions. These will be seen to be most similar when we examine the climax associations. One of the most noticeable features of the climax associations described for different parts of this province is the occurrence of Fagus in all of them, with a changing array of other species. The predominance of the beech is noticeable, however, only in the more northern localities and in the Alleghenies. Fagus has been listed in the climax associations of Alabama by Harper (1914), in North Carolina by Harshberger (1903), in Maryland by Shreve (1910), in Kentucky by Evans (1889), and in Pennsylvania by Harshberger (1904 B). In more northern regions it has been given a prominent place in the climax association as one of the dominant species. This has been shown by Roberts (1914) in Massachusetts, Nichols (1913) in Connecticut, Kearney (1900) in the Appalachians, and Bruncken (1902) in Wisconsin, as well as in Michigan (*vid. seq.*). There is an increase in the importance of Fagus as regards the climax association as one leaves the southern part of the province and approaches the contact with the northeastern conifer province.

III. Studies of the Climax Association in Michigan

A. Historical

The Lower Peninsula of Michigan lies in the edge of the deciduous forest province, and is also occupied by the southern border of the northeastern conifer province, besides receiving the outposts of the prairie province in its southwestern corner.

These facts are responsible for the great variety of associations present, and the successional relationships are often much involved in consequence. This may explain why these successional relations have been neglected by so many of the botanists who have described the vegetation of the State. Cowles (1899) described the climax for fixed dunes near Lake Michigan as a mesophytic beech-maple-hemlock forest in the maple-basswood series. He also described as climax forests coniferous woods alternating with oak woods on less mesophytic dunes. Although these last are apparently stable, they are not true climax associations, for they will gradually increase in mesophytism until the pioneer plants of the true climax may enter. Such associations should not be classed as "climax associations," but should be distinguished by some other term such as *temporary climax associations.* (Nichols, *l.c.*)

Although Transeau (1905 B, 1906) did not seem to recognize the position of the beech-maple series in the successions of southern Michigan, he described a forest of beech, maple, red oak, white elm, sycamore, basswood, and the like, as typical of the lake-plain. Coons (1911) found maples, elms, basswoods, and others, succeeding pines in the Saginaw region and concluded that the beech-maple type was the climax association. Livingston (1903) gave the beech-maple association as characterizing the heavier clay soils of Kent County, with some hemlock to the northwest. Gates (1912) described the beech-maple-hemlock as the climax for Cheboygan County. In the Northern Peninsula the beech-maple-hemlock was shown to be the climax by Whitford (1901). Ruthven (1905) and Adams (1905 A) found no Fagus in the Porcupine Mountains of the Upper Peninsula, though a climax forest of sugar-maple with a small amount of balsam-fir, basswood, and hemlock occurred there. Isle Royale was shown by Adams and Ruthven and also by Cooper (1913) to be dominated by a climax of spruce, birch, and balsam-fir, the climax for the northeastern conifer province; they noted sugar-maple as dominant on a ridge to the southwest, however, and recorded this as its extreme northern limit in the State.

B. COMPOSITION OF THE CLIMAX FOREST IN MICHIGAN

The climax forest in the Southern Peninsula of Michigan is a mesophytic forest characterized by deep shade beneath the dominants, and by a ground cover of moist humus. The dominant species are trees, but which of these are the true dominants can be recognized only by comparing their relative frequencies in the single habitats, and their occurrence in the several habitats. In Table I are given the percentage frequencies of some of the trees which commonly occur in this climax association. The percentage frequency was determined for each species by recording the number of times that it was seen within a distance of ten feet on either hand in making a line-transect through the individual association, and then expressing this in percentages in relation to the total number of all species thus noted. In this table not all of the species seen are included, for some were not abundant enough to make up one per cent of the trees, and hence were scarcely important as dominants; others were so typical of a preceding association as to warrant their exclusion. A few such as the white oak are scarcely typical, but occur so often that they were included as indices of the forest type.

As it was not possible to spend an entire summer at each of the stations concerned, the lists of secondary species are not complete; many of the more important secondaries can be recognized, however, at any time of the year, either by foliage, flower or fruit, or, if these be lacking, by remnants of these which often persist the entire winter and even far into the early summer. Quadrat studies for the frequency and abundance of the secondary plants (Clements, 1905) were made for many of the stations, but as they seemed of little value for the wide range of territory studied, they are not taken up in this paper. The secondary plants are of little importance in the association, except as indicators of the degree of dominance of the tree-species. Many are able to grow under any tree-growth as soon as conditions are sufficiently mesophytic, while others are entirely dependent on certain species of trees for their existence

because they are limited to special kinds of humus. The first sort often precedes the climax association, but the second comes in only when conditions have become relatively stable as regards the dominance of the trees of the climax association.

Dominant Species

The dominant species in the climax association are the trees listed as follows: *Acer saccharum*, *Betula lutea*, *Carya cordiformis*, *Fagus grandifolia*, *Fraxinus americana*, *Ostrya virginiana*, *Quercus rubra*, *Tilia americana*, and *Ulmus americana*. They are dominant by size and shading, interference with air-movement or wind-protection, and by humus formed from the fallen individuals or parts. Of these trees maples and beech make up about sixty per cent on the average, and the others mentioned make up about thirty per cent; the remaining ten per cent is made up by many different species of trees which vary in kind in the different parts of the State (See Table I). These less important trees are represented in the southern part of the State by *Liriodendron Tulipifera*, *Nyssa sylvatica*, *Platanus occidentalis*, *Prunus serotina*, *Quercus bicolor*, and *Sassafras variifolium*, and in the north by *Prunus pennsylvanica* and *Tsuga canadensis*.

Acer saccharum, the sugar-maple, is almost invariably present in the climax association as an important dominant. Although it is more frequent on clay soils, it is found on both clay and sand, the ratio of occurrence being about 2 : 1. The climax is reached more quickly on clay than on sand and this explains the present greater frequency on clay.

Betula lutea, the yellow birch, is frequently found in the association in the northern part of the State. Its distribution in the southern part is more scattered, but it may be found in every region of the Lower Peninsula.

Carya cordiformis, the bitternut hickory, occurs frequently in the southern consocies in this State, but is of general distribution as it occurs to some extent in the north also.

Fagus grandifolia, the American beech, is a most characteristic dominant of the beech-and-maple climax association. It is found most frequently on clay soils, but wherever sand has

had a sufficiently long development of humus, and where soil-water is not too inadequate, beech will develop with the other trees of the climax forest. The beech is considered by some to be an obligative mycorrhizal plant. If this be true, it will explain its restriction to good humus with plenty of soil-water

TABLE I

PERCENTAGE FREQUENCIES OF TREES IN THE CLIMAX ASSOCIATION OF SOUTHERN MICHIGAN

	Acer saccharum	Fagus grandifolia	Tilia americana	Ulmusa mericana	Fraxinus americana	Ostrya virginiana	Quercus rubra	Carya ovata	Prunus serotina	Carya cordiformis	Juglans cinerea	Quercus alba	Tsuga canadensis	Liriodendron tulipifera	Betula lutea	Other trees
REGION I																
Richmond	22	20	5	12	9	11	2	4	..	1	1	1	..	1	6	5
Wayne	9	22	2	6	6	..	8	2	..	2	..	5	..	1	..	37
REGION II																
Clayton	53	18	2	6	6	1	1	3	2	1	..	..	..	..	..	7
Ann Arbor	8	9	17	..	14	7	4	1	1	..	..	..	..	..	..	39
Charlotte	20	52	2	6	4	3	2	..	4	6	1	..	..	..	..	..
Davison	23	41	8	5	3	8	4	3	..	..	..	..	..	..	..	5
Clifford	48	19	6	13	3	5	..	..	1	..	..	..	1	..	..	4
REGION III																
Coldwater	45	39	3	3	..	7	..	..	..	..	2	..	..	..	..	1
Bronson	60	5	5	6	2	..	4	..	4	2	5	2	..	2	..	3
Berrien Springs	38	29	12	6	5	1	2	..	1	1	..	1	..	2	..	2
REGION IV																
Moseley	24	43	13	2	4	2	3	3	1	..	2	2	..	2	..	..
Clare	9	65	2	1	4	1	4	..	..	..	..	..	12	..	..	2
Hart	26	36	1	5	2	1	..	..	9	..	..	..	18	..	1	1
REGION V																
Vassar	23	68	2	..	..	..	..	...	..	..	..	2	..	..	..	5
Pigeon	8	12	4	36	..	..	1	2	..	..	3	..	..	..	4	30
REGION VI																
La Rocque	40	49	1	1	..	1	..	..	..	..	..	..	7	..	1	..
Douglas Lake	35	48	..	..	..	..	..	..	..	..	..	..	17	..	..	..

in regions where it is otherwise absent. The ratio of occurrence on sand and clay is about 1 : 2. Its distribution is general throughout the Lower Peninsula.

Fraxinus americana, the white ash, occurs indiscriminately on sand or clay throughout the Lower Peninsula, although it is less frequent towards the north where it is often replaced by *F. nigra*.

Ostrya virginiana, the hop hornbeam, occurs very generally in the State, but is more abundant in the southern consocies of the association.

Quercus rubra, the red oak, is often present in this association, especially in the southern part of the State. It is also a member of the oak-hickory association and occurs in the climax when it is on dry or "light" soils.

Tilia americana, the basswood, is a frequent member of this association and occurs throughout the peninsula, but more frequently on clay soils in the southern part.

Ulmus americana, the white elm, is a member of the climax association throughout the Lower Peninsula, especially in the southern part. Its ratio of occurrence on sand and clay is 3: 5 Next to the sugar-maple it is the most common member of this association.

Liriodendron Tulipifera, the tulip-tree, is not very abundant in any part of the State, but is most frequent in the southwest corner, where it is an important member of the association. On the western side of the peninsula it extends as far as a few miles north of the Grand River.

Nyssa sylvatica, the sour gum, is never an important tree in this association either as regards size or numbers. It is often present in the southern part of the State.

Platanus occidentalis, the sycamore, extends north of the Grand River as far as Sparta and Smyrna, both being not more than five miles north of the Grand River Valley. It is more frequently seen on sand, being prevalent in the river valleys. In the southwest and southeast parts of the State it is often seen in the climax association.

Prunus serotina, wild black cherry, is seen in most of the consocies of this association in the Lower Peninsula, but is not abundant in the northern ones. It grows to be a large tree, sometimes almost losing its distinctive bark character in age. In the north it is replaced by *Prunus pennsylvanica.*

Sassafras variifolium, sassafras, occurs as a shrub and as a tree very sparsely in the climax association. It is more characteristic in the oak-hickory association, and occurs in the stages of

succession of this association by the climax when the sugar-maple is present and is beginning to succeed the oaks. It was not seen in the northern part of the peninsula, but occurred as far north as White Cloud, forty miles north of the Grand River, and near Lake Michigan it was seen twenty miles north of Grand Haven.

Tsuga canadensis, the hemlock, occurs in the northern consocies, but extends south on both sides of the peninsula. Along Lake Michigan it is found as far south as the state-line between Michigan and Indiana; along Lake Huron it occurs as far south as Jeddo, not far from Port Huron, where it was seen on till-clay.

Shrub Zone

The shrub zone is variable in composition, in general being made up of young trees of the dominant species. The following are also characteristic of the shrub zone in the Lower Peninsula: *Amelanchier canadensis*, *Carpinus caroliniana*, *Ribes Cynosbati*, *Rubus allegheniensis*, *R. idaeus*, *R. idaeus aculeatissimus*, *Sambucus canadensis*, *Viburnum acerifolium*, and *Zanthoxylum americanum.*

Southern shrubs which enter the peninsula, but do not occur throughout are: *Aesculus glabra*, *Asimina triloba*, *Benzoin aestivale*, *Cornus alternifolia*, *C. paniculata*, *C. stolonifera*, *Corylus americana*, *Crataegus spp.*, *Morus rubra*, *Rosa humilis*, *Staphylea trifolia.* Those present in the north, but seldom or never seen in the southern part of the peninsula, are: *Acer pennsylvanicum*, *A. spicatum*, *Gaylussacia baccata*, *Rosa blanda*, *Sambucus racemosa*, and *Taxus canadensis.*

Rhus Toxicodendron is the only liana of nearly universal distribution in the Lower Peninsula. *Celastrus scandens*, *Clematis spp.*, *Dioscorea villosa*, *Smilax herbacea*, *S. hispida*, and *Vitis cordifolia* are southern, while *Lonicera canadensis* is northern, in distribution.

Secondary Plants

The secondary plants are mostly herbaceous, and, because of the lack of light, are not numerous in any of the patches of climax association. A large number of species occur in such

situations, but they vary from place to place. Those secondary plants showing the greatest frequency in the climax association and seldom found elsewhere are: *Actaea alba*, *Adiantum pedatum*, *Allium spp.*, *Apios tuberosa*, *Asplenium felix-foemina*, *Aralia racemosa*, *Arisaema triphyllum*, *Aspidium Goldianum*, *A. spinulosum*, *A. noveboracense*, *Botrychium virginianum*, *Carex plantaginea*, *C. tribuloides*, *Circaea alpina*, *Corallorhiza maculata*, *Cypripedium parviflorum* var. *pubescens*, *Cystopteris bulbifera*, *C. fragilis*, *Epifagus virginiana*, *Galium circaezans*, *G. tinctorium*, *Geranium Robertianum*, *Hystrix patula*, *Maianthemum canadense*, *Medeola virginiana*, *Mitella diphylla*, *Monotropa uniflora*, *Onoclea sensibilis*, *O. Struthiopteris*, *Osmorhiza longistylis*, *Osmunda cinnamomea*, *O. Claytoniana*, *Phegopteris Dryopteris*, *P. hexagonaptera*, *Podophyllum peltatum*, *Polygonatum biflorum*, *Polystichum acrostichoides*, *Smilacina racemosa*, *Thalictrum dioica*, *Trillium grandiflorum*, *Viola papilionacea*, and *Viola pubescens*.

Other secondary plants which are often found are not as typical. Of these *Aralia nudicaulis* is often present, but occurs also in the oak-hickory association, as does also *Mitchella repens*. Those occurring only in the southern consocies are: *Anemonella thalictroides*, *Asarum canadense*, *Carex conjuncta*, *C. filiformis*, *C. lupuliformis*, *C. lupulina*, *C. pennsylvanica*, *Erythronium albidum*, *E. americanum*, *Evonymus obovatus*, *Hydrastis canadensis*, *Laportea canadensis*, *Menispermum canadense*, *Phryma Leptostachya*, *Rhus canadensis*, *Trillium declinatum*, *Uvularia perfoliata*, *Viola canadensis*, *V. hastata*, *V. palmata*, *V. sororia*, and *V. striata*. Other secondary plants which are mostly northern in distribution are: *Actaea rubra*, *Botrychium ternatum*, *Clintonia borealis*, *Cornus canadensis*, *Gaultheria procumbens*, *Habenaria orbiculata*, *Linnaea borealis* var. *americana*, *Lycopodium annotinum*, *Mitella nuda*, *Pyrola asarifolia*, *P. elliptica*, *Smilacina stellata*, *Streptopus roseus*, and *Trillium cernuum*.

C. DISTRIBUTION OF THE CLIMAX FOREST IN MICHIGAN

The Lower Peninsula was divided, for convenience of study, into six regions which are separated from one another to some

MAP II. Regions of the Southern Peninsula of Michigan

The numbers on the map refer to some of the principal localities mentioned in the text: 1. Alma; 2. Alpena; 3. Ann Arbor; 4. Au Sable; 5. Berrien Springs; 6. Bronson; 7. Burt Lake; 8. Charlotte; 9. Clayton; 10. Clare; 11. Clifford; 12. Coldwater; 13. Davison; 14. Detroit; 15. Douglas Lake; 16. Eau Claire; 17. Eloise; 18. Grand Rapids; 19. Hart; 20. Kalamazoo; 21. Lapeer; 22. La Rocque; 23. Lowell; 24. Milan; 25. Mill Creek; 26. Mt. Clemens; 27. Moseley; 28 Olivet; 29. Omer; 30. Pigeon; 31. Plymouth; 32. Pt. Huron; 33. Richmond; 34. Sparta; 35. St. Joseph; 36. Smyrna; 37. Vassar; 38. Wayne; 39. White Cloud; 40. Willis; 41. Ypsilanti; 42. Zeeland.

extent by natural barriers; these are shown in Map II. In each of these regions a large number of stations were visited, but as space will not allow a detailed description of each station, they will be referred to only where they mark the limits of distribution of individual species.

Region I. The Southeastern Lake Plain

This region lies along the shore of Lake Erie and the Detroit River from the Ohio line as far north as Port Huron, extending back inland as far as the morainal ridges which parallel the lake margin at a distance of about twenty-five miles.

It is characterized by soils of lake origin, mostly lake clays and lake sands laid down in the glacial period. The soils best suited for the development of the climax in this region were somewhat "heavy" clays. The forests are dense and the shrubs and lianas not abundant, being usually limited to marginal zones. The soils are much modified by humus, and water relations are more toward the hydrophytic than the xerophytic extreme.

The dominants were much the same as those for the entire peninsula, being *Acer saccharum*, *Fagus grandifolia*, *Fraxinus americana*, *Tilia americana*, and *Ulmus americana*. *Betula lutea* was found at Richmond and *B. alba* at Mt. Clemens, both in the northeastern part of the region; *Liriodendron* was frequent throughout. *Acer rubrum*, *A. saccharinum*, *Celtis occidentalis*, *Fraxinus nigra*, *F. pennsylvanica* and *Nyssa sylvatica* were occasionally found in lowland habitats, while *Carya ovata*, *Juglans cinerea*, *Quercus alba*, *Q. macrocarpa*, *Q. rubra*, and *Sassafras variifolium* were often present in the upland habitats as relicts of the preceding oak-hickory association.

The shrub zone is made up of young trees of beech, tuliptree, hornbeam and cherry (*Prunus serotina*), and often of young oaks, hickories and sassafras where some interference has made light conditions favorable to these. *Sambucus canadensis* is the most abundant shrub, and besides those which are general in distribution, *Gaylussacia baccata* and *Vaccinium canadense*, which are mainly northern, occur here as far south as Willis.

The secondaries are in general those listed as "general" or "southern." The most frequent secondaries were *Evonymus obovatus* and *Smilacina racemosa*, which were found nearly everywhere. *Aralia nudicaulis*, *Aspidium noveboracense*, *Asplenium felix-foemina*, *Chimaphila umbellata*, *Cypripedium parviflorum* var. *pubescens*, *Medeola virginiana*, were not observed in any of the stations, although they occur in other southern regions. Plants scarce in the south were: *Aspidium Goldianum*, at Quirk's Woods south of Ypsilanti; *Gaultheria procumbens* at Wayne, and at Eloise; and *Smilacina racemosa* at Willis and at Milan.

Region II. The Inland Morainic Region

This region is made up of clay and sand moraines. It is located west of Region I and extends north to the Grand and Maple rivers, and west to the Looking-glass River along which the western boundary turns south to the state line (See Map II). The climax forest occupies both lowland soils and upland soils of lighter nature. The forests are generally dense and shady but with more undergrowth, the shrub zone being not limited to a marginal zone, but also present as a poorly developed layer within the forest. (See Plate XX, Fig. 1.)

The most abundant dominants for the region are: *Acer saccharum*, *Fagus grandifolia*, *Fraxinus americana*, *Ostrya virginiana*, *Prunus serotina*, *Tilia americana*, and *Ulmus americana*. In the lowlands *Acer rubrum*, *A. saccharinum*, *Betula lenta*, *Fraxinus nigra*, *F. pennsylvanica*, *Nyssa sylvatica*, *Quercus bicolor*, and *Ulmus fulva* occur also; *Juglans cinerea*, *J. nigra*, *Liriodendron Tulipifera* and *Quercus Muhlenbergii* occur in drier situations.

The shrub zone is composed of young trees of hickory, hophornbeam, wild cherry, red oak, sassafras and elm, and all of the shrubs of general and southern distribution for the State (excepting *Aesculus glabra*) and with the addition of *Corylus americana*, *Hamamelis virginiana*, *Rhus glabra*, and *R. typhina*, which abound here as well as in the north. *Sambucus racemosa* occurs here at Clifford in the northeastern part of the region.

Most of the secondaries are those listed as general or southern in the State. The following northern species were also present: *Asplenium felix-foemina* at Third Woods near Ann Arbor, *Medeola virginiana* near Lapeer, and *Mitchella repens* at Olivet. The following species, although probably occurring in other stations in this region, were not seen in any of those visited: *Aralia racemosa, Arisaema triphyllum, Aspidium Goldianum, Chimaphila umbellata,* and *Menispermum canadense.*

Region III. The Southwestern Outwash Region

This region is composed of soils similar to those of Region II, but more mixed with glacial outwash of both sand and clay. It comprises all of the west side of the State south of the Grand River Valley. The climax forest occurred on several soil types, sometimes well drained but with good humus. The shade is dense, but the shrubs occur in from one to three well-defined layers or stories under the dominants.

The most abundant dominants are: *Acer saccharum, Carya cordiformis, Fagus grandifolia, Fraxinus americana, Juglans cinerea, Liriodendron Tulipifera, Ostrya virginiana, Platanus occidentalis, Tilia americana,* and *Ulmus americana. Betula lutea* was not seen in any of the stations, and *Celtis occidentalis, Fraxinus quadrangulata, Juglans nigra, Prunus serotina, Quercus rubra,* and *Sassafras variifolium* were only occasionally found in the climax association here.

The shrub zone contains young trees of sugar-maple, bitternut, beech, tulip-tree, and sassafras in abundance, and all of the shrubs listed for general and southern distribution including *Aesculus glabra,* which was found frequently near Berrien Springs.

Of the secondaries of general distribution, *Actaea alba* occurred at Berrien Springs, though it is scarce in the southern part of the State. *Aralia racemosa, Aspidium Goldianum, Asplenium felix-foemina, Chimaphila umbellata, Cypripedium parviflorum* var. *pubescens, Medeola virginiana,* and *Onoclea Struthiopteris* were not seen in any of the stations. Most of

the southern species were seen with the exception of *Erythronium albidum*, *E. americanum*, *Laportea canadensis*, and *Uvularia perfoliata*. Of the northern species *Gaultheria procumbens* comes as far south as ten miles south of Zeeland.

Region IV. The Northern Morainal Region

This region is a large one as the study was made more especially for the southern part of the peninsula, and the stations of this and the two following regions were studied merely for comparison. This region occupies all of the western and central part of the peninsula north of the Grand River. Its soils are varied, being morainal sands and clays, outwash sands and clays, and a very small proportion of lake sands and clays especially dunes in the western shore region. The climax forest here occupies both high and well-drained soils and low boggy soils. In both situations it is dense and has much humus.

The most important dominants for this region are: *Acer saccharum*, *Betula lutea*, *Carya cordiformis*, *Fagus grandifolia*, *Fraxinus americana*, *Ostrya virginiana*, *Quercus rubra*, *Tilia americana*, *Tsuga canadensis*, and *Ulmus americana*. Near Alma and Clare *Betula alba* is often present in the climax; *Pinus Strobus* and *Larix laricina* often occur as relicts of past associations. In the southern border of the region some species of more southern range occur, as *Juglans cinerea* at Moseley and Alma, tulip-tree at Mill Creek and at Moseley, *Platanus occidentalis* at Mill Creek, and *Ulmus racemosa* at Hart.

The shrub zone contains those species listed for northern and general distribution as well as young trees of maple, bitternut, beech, hop-hornbeam, wild cherry, red oak, sassafras, and elm. At Moseley *Liriodendron Tulipifera* was found reproducing abundantly, so that young trees of this species made up a considerable part of the shrub zone, disproving Beal's statement (1904) that it is never found north of the Grand River Valley. *Zanthoxylum americanum* occurs as far north as Smyrna.

The secondary plants are those characteristic of the northern part of the State, with those of general distribution. A few

southern plants cross the barrier of the Grand River Valley, *Caulophyllum thalictroides* being seen at Alma and at Hart, *Evonymus obovatus* at Alma and at Clare, *Laportea canadensis* at Alma and at Moseley, *Phryma Leptostachya* at Alma and at Moseley, and *Uvularia perfoliata* at Hart.

Region V. The Saginaw Bay Region

The soils of this region are similar to those of Region I, being mostly lake sands and clays laid down in various ways. The region occupies the lands adjacent to Saginaw Bay to about twenty-five miles inland. Here the climax forest is characteristic as regards its secondary plants only on clay soils, but when present on sand a layer of humus covers the sandy surface.

The dominants are: *Acer saccharum*, *Betula lutea*, *Fagus grandifolia*, *Fraxinus americana*, *Tilia americana*, *Tsuga canadensis*, and *Ulmus americana*. The bitternut is only occasionally present, as are also *Fraxinus nigra* and *F. pennsylvanica*. As relicts from hydrarch successions *Acer rubrum* and *A. saccharinum* are often present, while *Carya ovata*, *Pinus Strobus*, *Populus grandifolia*, *P. tremuloides*, and *Quercus alba* are often relicts of the xerarch successions. *Juglans cinerea* is rare, being seen no farther north than Lapeer; *Platanus occidentalis* was seen at Vassar.

The shrub zone includes *Alnus incana* and *Corylus americana* as well as the shrubs listed for general distribution; northern shrubs present were *Acer spicatum*, *Gaylussacia baccata*, and *Rosa blanda*.

Secondary plants were nowhere abundant. The only secondaries of general distribution which were at all frequent were: *Adiantum pedatum*, *Apios tuberosa*, *Aspidium spinulosum*, *Chimaphila umbellata*, *Circaea alpina*, *Corallorhiza maculata*, *Cypripedium parviflorum* var. *pubescens*, *Epifagus virginiana*, *Mitchella repens*, *Osmunda cinnamomea*, *O. Claytoniana*, *Podophyllum peltatum*, *Viola papilionacea*, and *V. pubescens*. Secondary plants of northern distribution found here were: *Botrychium ternatum* var. *intermedium*, and *Gaultheria procumbens*. Southern species found here were *Arisaema triphyllum*, *Laportea canaden-*

sis, and *Rhus canadensis* at Pigeon, and *Evonymus obovatus* at both Pigeon and Vassar.

Region VI. The Northern Shore Region

In this region the soils are of all sorts, having clay and sand of all types. The region includes the tip of the peninsula from Little Traverse Bay to a point south of Alpena, and is a strip about twenty-five miles wide. The climax forest grows on all types of soil except bogs. Even on sand it has a well-developed humus layer, and in its dense shade a surprising variety of secondary plants are able to flourish.

The dominants are: *Acer saccharum*, *Betula lutea*, *Fagus grandifolia*, *Fraxinus nigra*, *Ostrya virginiana*, *Tilia americana*, and *Tsuga canadensis*. *Fraxinus americana* is only occasionally present, as is also *Prunus pennsylvanica; Tilia americana* is rare, probably reaching its northern limit in this region near La Rocque. (See Plate XX, Figs. 2 and 3.)

The shrubs are those listed as northern: *Acer spicatum*, *A. pennsylvanicum*, *Rosa blanda*, *Sambucus racemosa*, *Taxus canadensis*, and *Vaccinium canadense*. Those of more general distribution occurring here are: *Amelanchier canadensis*, *Carpinus caroliniana*, *Rubus allegheniensis*, *R. idaeus*, *R. idaeus* var. *aculeatissimus*, *Sambucus canadensis*. None of the species listed as southern occur here. *Rhus Toxicodendron* does not occur here as a liana in the forest, but is a shrubby plant which grows erect along sandy shores, and on dunes, so it is seldom found in this association.

The secondary plants include most of those listed as general or northern, but *Apios tuberosa* and *Mitella diphylla* were not seen in the region. The yellow ladies'-slipper here is confined to bogs, and *Gaultheria procumbens* prefers the pine association. *Trientalis americana* was present in the climax forests of this region, though not seen in the stations of any other region; *Habenaria orbiculata* occurred in Bryant's woods near Douglas Lake. *Viola palmata* was found in one station of this region, near La Rocque.

D. THE CAUSES OF THE PRESENT DISTRIBUTION

Climatic Factors

Neither the "isoatmic" lines of Livingston (1911) nor the temperature summations or "efficiencies" (Livingston and Livingston, 1913) are of value in explaining the distribution of plants within the State. The ratios of evaporation to rainfall (Transeau, 1905) are somewhat better, but they do not mark out the actual areas of distribution. That the relation is not merely one of rainfall is seen by examining such a map as that by Gannett (1909), which shows the amount of rainfall for the State. Drude (1890) shows a map of the floral regions based on the duration of the cold and warm months, and the line in Michigan which divides the southern part having a hot summer from the northern part having a moderate summer and a cold winter coincides much better with the southward extensions of the northern plants in the State.

The northern boundary for southern species in the State forms a V-shaped figure and the southern boundary for northern species forms an inverted V, as has been already mentioned by many writers concerning the vegetation of lower Michigan. The northern as well as the southern species are distributed farther from their centers of greatest abundance along both lakes, so that for either northern or southern species the boundary line curves either to the north or to the south in the central part of the peninsula. The more moderate climate of the lake shores allows the northern plants to remain here uninjured by the heat of the summer, and at the same time allows a northward advance of southern species in the same regions because of the lessened severity of the winter.

Edaphic Factors

1. *The chemical nature of the soil.* — The majority of the soil-studies that have been made, especially those dealing with botanical investigation, have been made with reference to the water-content of the soils. Some good work has been done on

the chemical nature of the soils; the work of Dachnowski on the effect of dissolved substances in the soil-water is one of these. Hollick (1880) and Evans (1889) classified plants according to the geological formations on which they occurred, and in Europe it has been customary to classify plants as to their soils, as in Tansley's *Types of British Vegetation* (1911).

The relation of vegetation to the chemical nature of the soil may be shown by the study of the soil analyses made by Kedzie (1893). As the forest-type was noted for many of his samples, it has been possible to combine his data into the following table in which twelve beech-supporting soils are compared with six pine-supporting soils.

TABLE II

Comparison of Beech- and Pine-supporting Soils

	Soils with beech			Soils with pine		
	Low	High	Average	Low	High	Average
Silicon	65.48	91.92	77.45	75.74	95.02	90.63
Aluminum	2.86	15.60	6.40	0.49	10.63	2.98
Iron	0.90	7.91	4.10	0.78	3.80	1.60
Calcium	0.40	1.64	1.11	0.20	0.94	0.41
Magnesium	0.13	1.23	0.60	0.12	0.48	0.22
Potassium	0.61	2.12	1.40	0.20	1.96	0.67
Sodium	0.28	1.20	0.76	0.26	1.25	0.72
Sulfate	0.10	0.30	0.21	0.05	0.26	0.10
Phosphate	0.13	0.49	0.30	0.01	0.44	0.14
Organic matter	2.05	7.48	3.90	1.34	2.97	2.13
Water	0.35	4.00	1.63	0.20	1.44	0.49

The amount of silica appears important, as the averages differ thirteen per cent; but while the five samples lowest in silica supported beech, and the four highest in silica supported pine, those between were beech-supporting on the ones having the higher silica content! The aluminum salts present indicated the amount of clay mixed with the sand, and although the four lowest in aluminum supported pine, the other pine soils con-

tained more aluminum than six of those supporting beech! Calcium has been supposed important for beech, but four of the beech-supporting soils were as low in calcium content as the highest of the pine soils, or even lower. Harper (1913) considered potassium more important than calcium for beech, but it was more abundant in two of the pine-soils than in six of the beech-soils; the four soils lowest in potassium were, however, pine-supporting.

There is seen in these samples a general tendency for soils higher in amounts of mineral nutrients to support a mesophytic forest, while those containing a higher proportion of silica support a xerophytic forest-type. Half of the samples could have supported either forest-type, as far as the mineral constituents were concerned. The original condition of the soil is not important as long as there are no harmful salts present, for it becomes richer as time goes on by the action of the vegetation.

The various stations studied were situated on soils of all kinds. A few examples will show the varied character of these soils. In Region I climax forest was present on lake clay (Milan, Plymouth, Quirk's Woods), on lake sand (Wayne, Willis, Richmond), and on morainal clay (Mt. Clemens). In Region II it was present on outwash sand (South Main St. woods near Ann Arbor), on morainal sand (Olivet), on till-clay (Third Woods near Ann Arbor, Davison, Charlotte), on morainal clay (Ypsilanti, Clayton, Lapeer, Clifford). In Region III the climax occurred on outwash sand (Kalamazoo), on outwash clay (Coldwater), on till-clay (Bronson, Eau Claire), and on morainal clay (Berrien Springs). In Region IV it was found on morainal sand (Mill Creek, Lowell, Hart), on till-clay (Moseley, Clare), and on morainal clay (Alma). In Region V it occurred on lake sand (Au Sable), on lake clay (Pigeon, Omer), and on morainal clay (Vassar). In Region VI it was present on outwash sands (Burt Lake), on morainal sand (La Rocque) and on morainal clay (La Rocque, Douglas Lake). The present distribution disproves, therefore, any statements as to chemical limitations based on the inorganic soil-constituents.

2. *Organic material, or humus.* — The analyses made by

Kedzie showed that the organic matter in beech-supporting soils is much greater than in pine-supporting soils. The presence of humus increases the amount of nitrogen present both directly in the nitrogen compounds of the fallen plant-parts and in the harboring of organisms which may be useful in fixing nitrogen. Humus increases the water-content by preventing surface-evaporation and by providing a spongy layer to absorb water and thus cut down surface run-off. Humus harbors many saprophytic bacteria and fungi which are of great value in changing the chemical and physical nature of the soil, and in some cases some of these are present on the roots of the trees in "mycorrhizas" which may be of benefit. Inorganic salts which have been brought to the plants from far beneath the surface by the roots are added to the surface soil by the fallen vegetative parts. It will thus be evident that the organic matter of the soil is of great importance as regards the mineral content of the surface soil, the water-content, nitrogen content, and biotic factors of the soil.

3. *Water-relations of the soil.* — The climax association occurs on soils which vary greatly in water-content. Conditions which are originally much too dry are made endurable for the climax forest by the development of a humus layer. On the other hand, conditions of saturation by water are remedied by the development of humus by other associations, and when the surface layers become sufficiently aerated, the climax can develop. The preponderance of the climax association on clay soils is because of the combination of water-relation and humus factors; these are mutually interdependent. Where water is present in sufficient amount, as is usually true of clay soils, humus develops quickly. Where water conditions are less favorable humus develops more slowly, but will in time so change the water-relations that the soil will become usable for the climax association. Wherever sand is sufficiently moist, humus develops and the climax is finally reached, and here, too, humus develops less rapidly on dry soils, but will in time accumulate so that the climax may develop. The difference between the availability of clay and sandy soils is mainly one of

time; in the case of sand a relatively longer time must elapse before a soil is fitted for the climax association.

Historical Factors

It is probable that one of the best explanations of the present distribution of the climax association is the relation to past conditions. The lack of northern forms in the south-central part of the peninsula is to be explained by the theory of Transeau (1903), that the land south of Michigan in Ohio and Indiana was never occupied by conifers, but that the deciduous trees followed the ice-retreat directly in this part of the State. It is probable that the majority of the plants entered the State from the southwest and southeast corners, and this would explain the farther penetration along the sides by so many species. The fact that the climax association of the southwest corner is of a high type, and occurs on sandy as well as on clay soils, indicates an entrance at this corner by many of the species, probably preceding the "xerothermic period,"[2] which ushered in the prairies of the southern part. It is probable that the climax association was present here in some places while the eastern corner was still under glacial waters.

E. FUTURE OF THE CLIMAX ASSOCIATION

The climax association does not occupy all of the available soils of the State at present. The amounts of nutrients in any soil are probably sufficient for plant growth, and wherever water and humus conditions are favorable, plant-growth will be present, and in time that plant-growth will be replaced by the climax association, provided the natural successions be undisturbed by fire or by man. In a few cases base-leveling must occur before the climax can develop. That there is now a tendency for the climax association to advance northwards is shown by the occurrence of maple forests on Isle Royale in Lake Superior. This advance is more gradual than any taking

[2] Adams, 1910; Alden, 1910; Brock, 1910; Coleman, 1910; Mathew, 1910; and Schulz, 1904, 1907, and 1908.

place in the Lower Peninsula, for the component species of the association are here near the edges of their ranges. In its northern outposts the advance of the association marks the advance of the province of which it is characteristic and is limited by climatic factors; within the province the advance upon other associations is limited only by edaphic factors, the majority of which are either biotic or are due to the previous action of biotic factors. The future of the association, therefore, depends first on non-interference, or rather protection, by man; and after that on the time element alone, for it is capable of occupying all of the soils of the State in time.

IV. Conclusions

1. The beech-and-maple climax association is an ecological unit for the southern peninsula of Michigan. The differences which occur between the climax forests of the northern and southern portions of the peninsula are not sufficient to warrant the division into two areas each having a different climax.

2. The differences in composition between the northern and southern consocies of the beech-and-maple climax association are due to the limits of distribution of certain of the component species.

3. The present climatic conditions fail to explain the present distribution of many of the component species of the climax association, as many of them are now migrating northward. *Liriodendron Tulipifera* is now extending its range to the north of the Grand River Valley, and is reproducing freely in the most northern station where it was seen.

4. The inorganic constituents of the soil do not act as limiting factors for the climax association. Although the climax association is usually found on clay soils rich in mineral salts, it occurs on all types of soil in all of the regions of the peninsula.

5. The organic matter of the soil is an important factor in determining the development of the climax association. Humus changes the physical composition of the soil, favors the development of soil organisms which may form mycorrhizas with the

roots of some of the higher plants, or may increase or render available the nitrogen supply, and also increases the inorganic constituents of the upper soil layers by the fallen plant parts which have derived these salts through the action of deeply penetrating roots from deeper layers. Wherever the climax association was found, a good humus layer was developed.

6. The water-relations are important only in the earlier stages of development of the climax association. As the water-retaining qualities of the soil may be increased or diminished by the addition of humus, any soil may in time support the climax association.

7. Historical factors are of great importance in explaining the present distribution of the climax association. The "lagging" of certain species in the central region of the State may be due to their having entered from one or both corners, and to their not having as yet completed their invasion of the central region. Many areas at present unoccupied by the climax association may be occupied in the future, when a sufficient time interval has elapsed for the modification of the present soils.

8. The present discontinuity and sparse distribution are due largely to the action of man. In the days of settling the wild country many regions were completely devastated of their virgin timber and have never recovered. The subsequent erosion of the surface soils has made recovery slower.

9. The beech-and-maple climax association is capable, if left undisturbed, of occupying eventually all of the soils of the Lower Peninsula of Michigan, and of perpetuating itself on them, and hence is a true climax association.

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EXPLANATION OF PLATE XX

FIG. 1. Beech with Undergrowth of Beech. Third Woods, near Ann Arbor. July, 1914.

FIG. 2. Ground-Cover of Young Maples at La Rocque. August, 1914.

FIG. 3. Trunk of Old Yellow Birch, La Rocque. 1914.

PLATE XX

Fig. 1

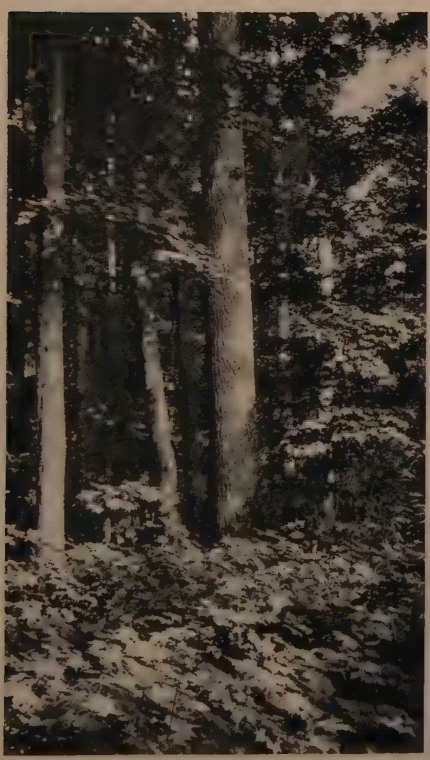

Fig. 2

Fig. 3

THE IMPERFECT STAGE OF SOME HIGHER PYRENOMYCETES OBTAINED IN CULTURE

LEWIS E. WEHMEYER

INTRODUCTION

During the fall of 1921 and that of 1922 various forms of the higher Pyrenomycetes were cultured from single spores or single asci. As a result of these cultures various imperfect connections described in the following pages were obtained. None of these forms have hitherto been connected by single spore or ascus cultural methods, and only two of them have been before suggested as integral parts of the same life-history. Since the taxonomy of both the perfect and the imperfect stages of these forms is in an unsettled and highly unsatisfactory state, it was deemed important that a number of life-history connections should be made; such connections seemed necessary to throw light upon the phylogenetic relations within the group. No final conclusions can be drawn of course from the small beginnings here presented.

Because of the present status of the classification of the fungi imperfecti, the forms studied are not placed definitely for the present; only their possible temporary position is suggested.

METHODS

All cultures were started either from single germinating spores, or single asci in which the spores were germinating. The following method was used. Thin sections were cut out from the center of perithecia with a safety razor blade and examined in a drop of sterile water on a flamed slide. In this way the condition of the spores and their number could be seen and regulated. These sections were then transferred by means of a needle, under sterile conditions, to from 5 to 10 c.c. of

water in a test tube, and there macerated until a spore suspension was obtained. A drop of this suspension could then be examined under the low power of the microscope, and the desired concentration of spores controlled. A quantity of this mixture was then drawn up in a capillary pipette, which had previously been sterilized in $HgCl_2$, and sprayed over the surface of an agar dish. By tilting the dish the liquid was spread evenly over the surface. A day or so later the culture was examined for germination. When a germinating spore or an ascus in which the spores were germinating was found, a line was cut on each side of it with a sterile needle, while still beneath the microscope. This block of agar was then removed and transferred to a second dish containing Leonian's agar, where a colony was allowed to develop. This agar was used on account of its transparency and because Leonian (in press) had shown it to be an agar highly favorable for pycnidial development.

When a pure colony was obtained in this manner from a single spore or ascus, it was transferred to various hard agars with high food concentration, which Leonian's work (4) suggested would be favorable for perithecial formation. In a few cases spore suspensions were at first made in liquid agar, which was then poured upon a sterile plate. This, however, necessitated examining the entire depth of the agar in order to be certain that a single spore would be cut out, and so was abandoned for the spray method, where the spores occurred on the surface of the agar only, and therefore simplified their isolation.

The nutrient media used will be referred to under the following names: nutrient agar,[1] Leonian's agar,[2] oatmeal agar,[3] agar No. 1.[4]

[1] That given by Duggar in *Fungous Diseases of Plants*, p. 26.

[2] The following nutrient solution plus 2% agar: KH_2PO_4, .125 gm.; $MgSO_4$, .0625 gm.; peptone, .0625 gm.; maltose, .625 gm.; malt extract, .625 gm.; water, 100 c.c. (in press).

[3] That given by Pethybridge and Murphy (*Sci. Proc. Dub. Soc.* 13: 580. 1913) as follows: ground Quaker oats, 60 gms.; cold water, 1000 c.c.; agar, various per cents used (2–6).

[4] The oatmeal agar indicated above plus the following nutrient solution: $CaNO_3$, .02%; $MgSO_4$, .02%; KH_2PO_4, .02%; NaCl, .1%; levulose, .1%.:

Sugar-oatmeal agar was made by adding five per cent cane sugar to the oatmeal agar. Oatmeal agars were made by adding an infusion of approximately 100 gms. of the bark of beech, maple or other trees to enough hard oatmeal agar to bring the total to 1000 c.c. Plain infusion agars were made by adding twenty per cent plain agar to the type of infusion described above.

All twigs used for culture purposes were placed in test tubes containing 3–5 c.c. of water, and sterilized at 15 lbs. pressure for 2 to 3 hours.

DIAPORTHE ONCOSTOMA (Duby) Fck.

Perithecia

The stromata of the perfect stage of *Diaporthe oncostoma* (Duby) Fck. on *Robinia pseudo-acacia* L. break through the periderm in a rather ragged manner, forming a small irregular blackened pustule .5–1.5 mm. in diameter, and containing 1–8 short cylindrical or conical ostioles, which soon crumble away leaving a misshapen mass. In a vertical section of the twig (Pl. XXI A, Fig. 1), the perithecia are seen to be scattered singly or in clusters 2–3 mm. in diameter, and containing 2–8 perithecia. The perithecia are spherical or ellipsoidal, and measure 450–600 x 400–450 μ. They are buried in the altered bark tissues, which become bleached or whitened to such an extent, that, even with a hand lens, they can scarcely be distinguished from the woody tissue. This whitened area in the bark corresponds to the white stromatic tissue formed on agar, as in young stages the pycnidia can be found imbedded in this stroma directly above the perithecia. The surface of the bark just beneath the periderm is blackened, and in section appears as a dorsal dark line connecting adjacent stromata. At the termination of groups of stromata this line dips deeply into the wood, and then returns in an irregular fashion to a point 2–3 mm. below the stromata, delimiting an area of mycelial growth. The asci (Pl. XXI A, Fig. 6) are cylindrical-clavate, 60–67 $\times$ 7–8 μ, and are accompanied by evanescent paraphyses. The spores (Pl. XXI A, Fig. 5) are biseriate, ovoid, fusiform, 2-celled,

hyaline, slightly constricted at the septum, usually with four oil-drops in each cell; they measure 13–16 $\times$ 3–4 μ.

Pycnidia

Diaporthe oncostoma (Duby) Fck. was collected in the fall of 1921 on the branches of *Robinia pseudo-acacia* L. Sprays of ascospores from this were made upon Leonian's agar, as mentioned above, on January 18, 1922. Twenty hours later these spores were germinating profusely, and single germinating spores as well as asci in which the spores were germinating, were transferred to tubes and petri dishes containing plain oatmeal agar and agar No. 1. All the colonies produced a heavy growth of superficial white mycelium, and soon formed a blackened area at the surface of the agar.

On March 2, the first pycnidium was observed in the tube of agar No. 1, which had been inoculated on February 13 from a single spore colony isolated from a spray made on February 9. Following this observation pycnidial stromata were formed in profusion in numerous cultures of the agars mentioned above.

The size and shape of these stromatic masses and their contained cavities were very variable on agar. The general structure, however, of the various forms showed them to be due merely to the relative development of the various tissues concerned. In general the cavities are formed in a white stromatic area composed of hyaline hyphae. This stromatic tissue is formed upon and above the blackened surface of the agar, which is in turn composed of more or less fused brownish hyphae. The white stromatic area is circumscribed laterally, as seen in vertical section, by a superficial dark line. In the simplest and smallest stromata the cavities are irregularly lens-shaped, and lie upon the surface of the blackened agar just beneath the superficial mycelial growth with very little development of the stromatic tissue about them. In the more extensive stromatic formations (Pl. XXI A, Fig. 3), often formed on the same plate as the smaller ones, the cavities are larger and frequently form projections from the base or sides of their walls, making an irregular cavity buried in a well-developed stroma. The stro-

mata, furthermore, often become compounded and form large tuberculate masses 2–5 mm. in diameter.

In the less stromatic fruit-bodies the cavities have a thick dark wall composed of heavily darkened parenchyma cells (Pl. XXI A, Fig. 4). This wall is lined by a narrow layer of hyaline tissue which bears the conidiophores. In the more extensive stromatic formations, this wall may be almost or entirely lacking. These larger formations, with their greater development of rapidly growing hyaline, stromatic tissue and lack of darkened cavity walls, seem to be the result of a higher moisture content or other favorable conditions of mycelial growth.

Two types of spores are formed corresponding to the alpha and beta spores mentioned by Diedicke (2), or to the pycnospores and scolecospores, as referred to by Shear (7). The first type (Pl. XXI A, Fig. 8) is a hyaline, one-celled, fusoid spore, $8–10 \times 2–2.5\ \mu$, born on filiform conidiophores measuring $20–25 \times 2\ \mu$. The second or beta type (Pl. XXI A, Fig. 7) is a long, filiform, hamate, hyaline, one-celled spore, measuring $13–22 \times 1–1.5\ \mu$. These spores are produced either directly from the subhymenium or often on more or less fusoid conidiophores. The hamate type seems to be produced first, or it may appear under favorable growth conditions; they are the tips cut off from the rapidly growing conidiophores, and are followed by spores of the fusoid type.

The spores are ejected through a pore in the apex of the stroma in the form of a spore horn. The color of these spore horns varies from white to pinkish, depending upon the relative amounts of the two types of spores composing them. The spore horns of a pinkish tint are made up almost entirely of fusoid spores, while the others of a yellowish or white color contain mostly spores of the hamate type.

The imperfect form was also found on Robinia in association with *D. oncostoma;* here the pycnidia were found in the whitish stromatic substance which formed on the surface of the wood and pushed the periderm into small pustules 1–2 mm. in diameter.

The imperfect stage of the fungus belongs to the genus Phomopsis, as limited by Diedicke (2), since it has the stromatic

development of the fruit-body, the thick indefinite outer wall often of darkened cells, with an inner layer of hyaline cells bearing the conidiophores, the projections from the basal and side walls of the cavities, and the two types of spores of that genus. The only previous connection in regard to this species is that of *Phoma oncostoma* Thum., made by observation only, and referred to by Saccardo (5).

QUATERNARIA PERSOONII (Pers.) Tul.

Perithecia

The perfect stage of *Quaternaria Persoonii* (Pers.) Tul. on *Fagus grandifolia* Ehrh. forms thickly scattered, hemispherical-conical pustules, .8–1 mm. in diameter; they are erumpent in the form of a small central disc composed in part of 3–6, united, irregularly hemispherical ostioles. The stromata are always densely crowded, becoming in some cases, for example in the Ann Arbor specimens, united into a continuous raised layer over extensive areas of the branch surface; the perithecia and erumpent discs are evenly and thickly scattered. This condition approaches an effused Diatrype in all respects, except that the perithecia are erumpent in clusters rather than singly. In vertical section (Pl. XXI B, Fig. 1), the bark tissues are seen to be differentiated into three distinct regions: the upper is a corky tissue in which the spherical or ellipsoidal perithecia, measuring 350–450 $\times$ 200–350 μ, are imbedded; below this there is a narrow light-colored area made up chiefly of stone cells; the third zone is the thick blackened area forming a black stratum of bark resting on the wood surface. The asci (Pl. XXI B, Fig. 2) are clavate and measure 52 $\times$ 5 μ. The ascospores (Pl. XXI B, Fig. 3) are biseriate in the ascus, allantoid, brownish-hyaline, and measure 10.5–13 $\times$ 2.5–3 μ.

Pycnidia

A specimen of the American form of *Quaternaria Persoonii* (Pers.) Tul. was collected on twigs of *Fagus grandifolia* Ehrh. by Lee Bonar in the fall of 1921 in West Virginia. On March 16, 1922, sprays of ascospores were made from this

specimen by the usual method. Twenty-four hours later germ tubes were growing out from both ends of the spores. Single germinating spores and asci were isolated and transferred to agar No. 1, and later to beech-oatmeal agar. A dense cottony growth was formed on both agars.

No fruit-bodies were formed on a set of 4–5 identical cultures on oatmeal agar, but a transfer to two capsules of beech-oatmeal agar on May 3 showed pycnidia on June 3. Upon examination these proved to be loose, stromatic, lens-shaped structures, with circular flattened locules, and with small projections from the walls. They opened through a central pore from which an orange-colored spore horn projected. The locular walls were delicate and consisted of a narrow band of darkened hyphae bordering the locule. The spores were filiform, hyaline, one-celled, and strongly curved, measuring 13–20 $\times$ .5–1 μ. They were abstricted from the ends of the loose hyphae just inside the darkened locular walls. Spores were also abstricted from the sides of the conidiophores. They often occurred in clusters of 2–3 at their tips.

On May 26, 1922, sterilized healthy beech twigs were inoculated with hyphae from a single ascus culture and stored in a cold room, kept at or below 10° C during the summer. In November these twigs were found to have spore horns emerging from circular lens-shaped pustules. An examination of these in January, 1923, showed a pycnidial formation similiar to that on agar (Pl. XXI B, Fig. 4). Here also the pycnidial wall was very indefinite, consisting usually of a discontinuous blackened layer along the base and sides of the locule. Inside of this wall was a hyaline prosenchymatous tissue from which the conidiophores arose (Pl. XXI B, Fig. 5). This tissue often formed projections or ridges running into the cavity, which sometimes extended upward to the periderm, thereby forming partitions in the main locule. The locule was at first covered by the periderm, and the spores were at length ejected through a pore as an orange-colored spore horn. Although there was often a thin layer of prosenchyma on the lower side of the periderm, which sometimes produced a few spores, this was comparatively

slight and might easily escape observation. The spores (Pl. XXI B, Fig. 6), like those in the pycnidia formed on agar, were filiform, hyaline, one-celled, strongly curved, and measured 13–20 × .5–1 μ. They were born on filiform conidiophores.

An imperfect form on Fagus associated with *Quarternaria Persoonii* was found in the fall of 1922. Upon examination this proved to be identical with that found in culture. In this case the orange spore mass at maturity shone through the periderm, and gave the effect of orange-colored spots upon the twig. The periderm also showed a tendency to break away in old age. L. R. and C. Tulasne have figured the imperfect stage of *Q. Persoonii* (8, Pl. XII, Figs. 16–25), referring it to the synonymous species, *Naemospora crocea* (Pers.) Moug. Nestlero, and *Libertella faginea* Mazerio.

Since our fungus fits the descriptions of *Libertella faginea* and can not be said to have a continuous pycnidial wall, it is temporarily referred, to use the old nomenclature, to *Libertella faginea* Mazerio. The spores of *L. faginea* are given by Allescher (I, p. 735) as 30–35 × 2 μ, or in his *forma minor* with spores 18–25 × 1 μ.

The European descriptions of the perfect stage of *Q. Persoonii* give the measurement of its ascospores as 14–20 × 4 μ (9, p. 824). European exiscatti (*Syd. Myc. Germ.*, Nos. 73 and 1577) did not show such a large discrepancy, since these specimens have spores 13–16 × 2.5–3 μ. The stromata of the European specimens are also larger than those of the American form. Ellis remarks on this point on his exiscatti of *Valsa quaternata* (*N.A.F.*, 175) on maple, which has smaller stromata even than the form upon beech. As was seen above, the imperfect stage gave correspondingly smaller spore measurements, a condition which points to the fact that we are dealing here with an American form of *Q. Persoonii*, somewhat different from that in Europe.

DIATRYPE VIRESCENS (Schw.) Berk.

Perithecia

The perfect stage of *Diatrype virescens* (Schw.) Berk. on *Fagus grandifolia* Ehrh. forms irregular, 3–4 angled, pulvinate, erumpent stromata, with the persistent ruptured periderm about

their edges. The stromata are 1–2 mm. in diameter and .8 mm. in height. The surface is a brilliant grass-green about the edges, with a light-yellowish center, in which are scattered the 6–15 round, flat, scarcely erumpent, quadrisulcate, black ostioles. In vertical section (Pl. XXI C, Fig. 1) the white interior of the stromata, in which the perithecia are imbedded, is seen to be bounded on the surface by a darkened surface layer of tissue. The stroma is seated on the surface layers of the bark just beneath the periderm, but the dark line extends through the bark and slightly into the wood surface, cutting off an altered whitened area of bark tissue, and spreading out as a darkened area on the wood surface. The perithecia are oblong-cylindrical, with rather short stout necks terminating in the flattened ostioles. They measure $400–535 \times 250–420\ \mu$. The asci (Pl. XXI C, Fig. 2) are clavate, long-pedicellate, with a thickened, truncate apex; the p. sp. measures $29–35 \times 4.5–5\ \mu$, the pedicel $40–55\ \mu$, and the apex $25\ \mu$. The spores (Pl. XXI C, Fig. 3) are biseriately arranged in the ascus, allantoid, yellowish-hyaline, and $8–10 \times 2.5\ \mu$.

Pycnidia

Ascospores of a specimen of *Diatrype virescens* on *Fagus grandifolia* were suspended in melted nutrient agar, and plates of this suspension were poured on December 23, 1921. Twenty hours later the spores had germinated by means of long narrow germ tubes. On January 18, 1922, sprays of ascospores were made on Leonian's agar, and single germinating spores and asci were isolated.

Colonies from these spores or asci grew well on both agar No. 1 and sugar-oatmeal agar, but produced no fruiting bodies. On May 3, transfers from a single ascus strain was made to beech-oatmeal agar. On June 3, spore masses were found in these cultures. They were apparently open acervuli which were at first imbedded in the superficial, cottony weft of mycelium (Pl. XXI C, Fig. 4). The exposed spore masses were of a deep orange color, from .2–1 mm. in diameter, and often confluent. The acervulus contained a compact mass of filiform, one-celled,

hyaline spores, slightly bent, and measuring 23–34 × 1–1.5 μ; these spores were abstricted from the tips, and sometimes from the sides, of the intertwined hyphae beneath.

On May 26, sterilized beech twigs were inoculated with mycelium from a single ascus culture and stored in a cold room (below 10° C) over the summer. This culture developed under comparatively dry conditions, and showed very little superficial mycelial growth, while a second one, made on November 16 from a single ascus and transferred to sterilized beech twigs, was kept under moist conditions and gave a prolific growth of mycelium. Both cultures were examined on February 6; because of the difference in moisture conditions, the structural variations in the two cultures were quite wide, but showed themselves to be due to the relative development of certain common tissues. In the drier culture the pustules were entirely covered by the periderm (Pl. XXII C, Fig. 5), and the spores were emitted as spore horns. In vertical section large masses of spores were observed, which had been cut off from a broad, but rather scanty, hyaline, stromatic tissue seated just beneath the periderm.

In the moist culture, on the other hand, the growth of this mycelial stroma was greatly stimulated, with the result that it pushed up through the periderm, forming a Tubercularia-like cushion on the surface (Pl. XXII C, Fig. 6). The spores were abstricted from the surface of this stroma. Spores were also cut off in the interior of this stromatic mass, in which indefinite chambers were formed, which, however, usually opened to the exterior. The spores (Pl. XXII C, Fig. 8) were filiform, hyaline, slightly bent, and measured 23–31 × 1 μ. They were born on filiform conidiophores 26–30 μ in length.

On account of the wide variation of the imperfect stage under culture conditions, it could be placed in widely differing groups of the fungi imperfecti. For this reason the form is not referred to any particular genus at present.

So far as can be determined, the imperfect stage of *D. virescens* has never been published; this is at least the first cultural connection by means of single spore or ascus strains.

DIATRYPELLA FROSTII Pk.

Perithecia

The perfect stage of *Diatrypella Frostii* Pk., as it appears on *Acer saccharum* Marsh., forms hemispherical, or longitudinally elongated, pulvinate pustules, .8–2 mm. long, which are often confluent in longitudinal rows. These pustules are erumpent, and form a small disc, which is at first yellowish-green and pulverulent, but soon weathers to a dirty grey. The disc contains 2–6 circular, flattened, and often sulcate ostioles. In vertical section (Pl. XXII D, Fig. 1), the perithecia are seen to rest upon the inner bark, and lie buried within the periderm which is raised into a pulvinate pustule. The perithecia are spherical, 500–800 μ in diameter, with thick walls (23–28 μ), and are surrounded by a thin layer of a yellowish-green substance like that of the disc. A ragged dark line extends down from each side of the stroma through the bark cortex to the surface of the wood; here it spreads out as a darkened stratum between bark and wood. The area of bark cortex within this line is lighter in color than the remainder of the bark. The asci (Pl. XXII D, Fig. 2) are polysporous, broad-clavate, long-pedicellate, and with an acute, thickened apex; the spore-bearing portion measures 98–100 $\times$ 15–16 μ, while the pedicel is 50 μ long. The spores (Pl. XXII D, Fig. 3) are crowded in the ascus. They are small, allantoid, yellowish-hyaline, and measure 5–6 $\times$ 1.5–2 μ.

Pycnidia

A culture from a single ascospore transferred to sugar oatmeal agar on February 1 showed the imperfect stage on June 3. On this agar the pycnidia were irregular spherical bodies, often confluent or compounded into larger masses. The locules also varied; the simple and what may be called normal ones were spherical, with a thick black parenchymatous wall; these by confluence often became irregular or even labarynthiform and opened to the exterior by a wide exit. The spores were born on an inner layer of hyaline, filiform conidiophores, 26 μ long. The spores were long-filiform, hyaline, one-celled, variously curved or bent, and measured 18–30 $\times$ 1 μ. The conidiophores arose from all parts of the wall.

On November 17, 1922, sterilized beech twigs were inoculated with mycelium originating from single ascospore cultures. By the latter part of December spore horns appeared on these twigs and an examination on January 28 showed pycnidia (Pl. XXII D, Fig. 4). These originated from a stromatic patch of mycelium immediately beneath the periderm and soon developed a pycnidial cavity. The cavity was bounded beneath by a somewhat darkened area of bark cells and above by the periderm. The interior was lined with a layer of hyaline, prosenchymatous tissue (Pl. XXII D, Fig. 5) bearing the filiform conidiophores, which measured 20–26 $\times$ 1 μ. This conidiophorous tissue often formed minute projections into the pycnidial cavity. The inner surface of the periderm also bore a thin layer of this fertile tissue with spores. The spores (Pl. XXII D, Fig. 6) were filiform, hyaline, curved, and measured 30–50 $\times$ 1.5 μ, and were, therefore, longer than those on agar.

Under moist conditions in the test tube cultures, a stromatic mycelial cushion often formed on the twig above the immersed locule. In this stroma a second cavity arose, often connecting with the one beneath the periderm. In these cases a thick dark wall developed about the pycnidial locule in the stroma. The spores were pushed out through a pore in the form of a long, orange, thread-like spore horn.

The structure of this fructification is similiar to that of *Quaternaria Persoonii*, except that on agar it forms a thicker and darker wall, and on twigs a more definite layer of conidiophores is formed on the under side of the upper peridermal wall. No connection of any imperfect stage with *D. Frostii* has apparently been made up to this time.

VALSARIA EXASPERANS (Gerard) E. & E.

Perithecia

The stromata of the perfect stage of *Valsaria exasperans* (Gerard) E. & E. on *Acer saccharinum* L. are arranged in longitudinal rows and are often confluent for long distances (1–10 cm.). They are pustulate, 1–1.5 mm. high, and terminate above in an elongated, brownish, pulverulent disc, .8–1 $\times$ .5 mm.

in diameter; by confluence the disc may exceed this length. The ostioles are hemispherical, black, punctate, and lie scattered in the stromatic disc. In vertical section (Pl. XXII E, Fig. 1) a definite, oval or elongated stroma of strongly altered bark cortex can be seen lying on the surface of the inner bark just beneath the periderm. The stromata are mouse-grey within, and darken towards the margin, but there is no darkened area in the host tissues beyond. The perithecia are irregularly elliptical, 300–400 × 180–250 μ, with walls 8–10 μ thick, long narrow necks, and arranged in an irregularly polystichous manner within the paler area of the stromata. The asci (Pl. XXII E, Fig. 2) are long and cylindrical, with a sharply constricted, pedicellate base, and measure 100–120 × 10–11 μ. The spores (Pl. XXII E, Fig. 3) are uniseriate, broadly fusoid, two-celled, brown, constricted at the septum, with blunt ends, and measure 13–15 × 8–9 μ. The paraphyses are long-filiform.

Pycnidia

Sprays of ascospores from perithecia on *Acer saccharinum* L. were made on December 1, 1922 upon Leonian's agar. Forty-eight hours later spores were found well along in germination; the mycelium which was formed was characteristic of both species of Valsaria studied. A dense colony of radial many-branched hyphae appeared, which soon developed numerous smaller lateral branches, and these in turn proliferated rapidly and broke up into an oidia-like formation. About this time brownish hyphal branches began to be formed. The colonies showed scanty superficial growth except at the margin of the colony. Transfers to plain infusion agars of Acer and Quercus bark produced only a very scanty mycelial growth of superficial hyphae.

Ten days after transfers were made to plain oatmeal agar from the spray mentioned above, hemispherical stromatic bodies, 1–3 mm. in diameter, were formed on the surface of the agar, and about four days later, large, brilliant-vermillion spore masses were found exuding from these stromata. After spore formation had begun, the mycelium took on a pinkish to yellowish color, at first in spots, and finally over the entire culture. This coloring of the mycelium was also noticed at the apex of the

stromata formed on wood under moist conditions. The locules were numerous and labarynthiform, and were formed in a dark black, ovoid or spherical stroma, 1–3 mm. in diameter, which was in turn imbedded in the superficial weft of mycelium. The stromata were often confluent. The walls of the locules were composed of a dark pseudo-parenchyma with a few layers of lighter-colored cells lining the cavity, from which the fertile conidiophore layer arose. The conidiophores, measuring 13–15 $\times$ 2 μ, were hyaline and somewhat swollen in the central portion so as to appear like ten-pins in shape. They abstricted the conidia from their tips. The spores were minute, oval, hyaline, 1.5–1.75 $\times$ 1 μ, and were produced in enormous quantities.

On January 17, 1923, sterilized twigs of *Acer saccharinum* L. were inoculated with mycelium from a single ascospore culture of *Valsaria exasperans.* On January 30, the stromata were noticed near the point of infection, and 5–6 days later were forming throughout the length of the twigs. The moisture content of this culture was high, and hence large spherical, superficial stromata, 2–5 mm. in diameter, with a thick, superficial, upright, hyphal growth were formed. The stromata originated beneath the periderm, but broke through and were soon entirely superficial. The interior structure was identical in all respects with the stromata formed on agar.

Since the pycnidial stromata were many-chambered, labarynthiform, and bore oval, hyaline spores, this stage must be referred to the form-genus Cytosporella. So far as has been ascertained, this is the first time an imperfect stage has been connected with the life-history of *Valsaria exasperans.*

VALSARIA INSITIVA Ces. & de Not.

Perithecia

The stromata of *Valsaria insitiva* Ces. & de Not. appear as small, swollen, pulvinate pustules raising the periderm of its host into irregular elliptical swellings 1.5–2 mm. in diameter and often confluent over wide areas. Minute, circular discs, consisting of stromatic plugs are scattered over the fruiting area in what seem to be an irregular fashion; this appearance is due

to the fact that many aberrant plugs are formed which do not connect with the perithecia, or do not even occur upon a stroma. The numerous flask-shaped perithecia, 300–500 × 200–300 μ in diameter are, however, arranged in a circinate manner in the slightly altered bark. Their necks all point toward, and are connected with, a central pore, which perforates one of the plugs previously mentioned, and is capped by a four-sulcate, black, carbonaceous ostiole. The stroma rests on the surface of the wood, which is more or less blackened, often forming, as seen in vertical section (Pl. XXIII F, Fig. 1), a definite dorsal line running between the bark and wood. This line here and there penetrates deeply into the wood in a ragged manner. The stroma becomes carbonaceous and brittle-crumbly with age. The asci, which are cylindrical, measure 100–120 × 8–10 μ. The paraphyses are filiform and rather numerous. The spores are broadly fusoid, two-celled, brown, constricted at the septum, with blunt ends, and measure 13–17 × 6.5–8 μ.

There is some variation in the spores and asci on different hosts. Saccardo has separated out the two following forms (6): form Linderae Sacc. on *Lindera benzoin* Blume with asci 95–120 × 14–15 μ, and spores 16–18 x 8–9 μ; form Colutae Sacc. on *Colutea arborescens* L. with asci 100–120 × 11 μ, and spores 16–18 × 9–11 μ.

Spore measurements made from specimens collected on the following hosts were found to be as follows: on *Cercis canadensis* L., 15.5–17 × 7–8 μ; on *Ulmus americana* L., 13–15.5 × 6.5–7.5 μ; on *Ptelia trifoliata* L., 15–16 x 7–8 μ; on *Lindera benzoin* Blume., 13–15.5 × 7.5–9 μ. The specimen on *Ptelia trifoliata* showed practically no raising of the periderm into pustules; the stromata were very much flattened. Although the spores from Cercis tend to be longer in comparison with their width, while those from Lindera tend to be shorter than the normal, yet the differences are so slight that it does not seem necessary to take them into account.

Pycnidia

On November 21, 1922, two agar dishes were sprayed in the usual manner with ascospores from perithecia of *Valsaria insitiva*

on *Ulmus americana* L. Forty-eight hours later one of the cultures had germinating spores, and was forming radial colonies of rapidly growing dense hyphae much as described for *Valsaria exasperans*. Transfers of single spores and asci to oatmeal agars produced a white, appressed, cottony growth and soon formed a blackened area upon the surface of the agar. Transfers to plain infusion agars yielded a sparse growth with very little aerial hyphae. The transfers to Acer, Fagus, and plain oatmeal agars, of November 25, 1922, had all begun to show hemispherical raised areas by December 1. A week or ten days later these began to exude orange-colored spore masses. Upon examination the pycnidial cavities (Pl. XXIII F, Fig. 2) were found to be numerous and labarynthiform. They were imbedded in a black stroma which was surrounded to a greater, or lesser extent, by a cottony, mycelial growth, especially under moist conditions. The stroma was seated either directly upon the blackened surface of the agar or separated from it by an area of this cottony growth. The locules were lined with a layer of light-colored cells (Pl. XXIII F, Fig. 3) from which arose the fertile layer of hyaline conidiophores; these were somewhat like ten-pins in shape, and abstricted from their tips the small, oval, hyaline, one-celled spores (Pl. XXIII F, Fig. 4), measuring 2–2.5 × 1–1.5 μ.

The structure of this fruit-body would also place it in the form genus Cytosporella. No previous mention of this imperfect stage in the life history of *V. insitiva* has been found.

DIAPORTHE FURFURACEA (Fr.) E. & E.

Perithecia

The stromata of *Diaporthe furfuracea* (Fr.) E. & E. on *Tilia americana* L. appear on the surface as minute fascicles of 3–6 ostioles, each fascicle measuring .3–.6 mm. in diameter. The ostioles are at first short-conical, becoming long-cylindrical and carbonaceous. In vertical section (Pl. XXIII G, Fig. 1) the perithecia are seen to be buried in the unaltered bark tissue between the bast fibers. They are large, 400–600 μ in diameter, thick-walled (13–17 μ), and with long, narrow necks penetrating the slightly stromatic disc, which is often surrounded by a faint

dark line in horizontal section. The asci (Pl. XXIII G, Fig. 2) are broadly clavate, with a refractive ring at the base of the thickened tip, and measure 80–120 × 13–18 μ. The spores (Pl. XXIII G, Fig. 3) are biseriate in the ascus, fusoid, two-celled, hyaline, constricted at the septum, filled with several large and many smaller oil-drops, and measure 20–30 × 5–8 μ.

Pycnidia

Sprays of ascospores of *Diaporthe furfuracea* from perithecia on twigs of *Tilia americana* L. were made in the usual manner on December 1, 1922. Thirty-two hours later germination had begun. When spores and asci were transferred, however, to Leonian's agar, very little growth took place during the first seven days. At the end of that time small colony growths became visible and were transferred to various media.

A transfer from a single ascospore culture was made to plain oatmeal agar on January 4, 1923. About February 15 a formation of hemispherical stromatic bodies appeared, arranged in concentric rings about the point of inoculation. They were at first minute and covered with a whitish mycelium, but later grew to a diameter of 1.5–3 mm. and the surface became blackened by the oozing out of blackish droplets of spores. In vertical section these stromatic cushions were seen to be composed of an inner, less compact mass of tissue, surrounded by the raised discolored tissue of the surface of the agar. Within this prosenchymatous tissue were seen a few small scattered cavities without walls, within which were cut off the spores from the ends of the surrounding protruding hyphae. These spores were elongate-fusoid to cylindrical, hyaline and two-celled. A large percentage of them were abnormally bent and twisted. They measured 15–36 × 4–6 μ. The entire structure seemed to point to an abnormal or unhealthy development, which seemed to be borne out by the results obtained on twigs.

On December 10, 1922, sterilized twigs of *Tilia americana* L. were inoculated with mycelium from a single spore culture of *Diaporthe furfuracea*. On January 23, 1923, whitish to yellowish spore horns were found emerging from these twigs. The first

fruit-bodies, formed near the point of inoculation, had an abnormal development of the stromatic tissues due to the high moisture content of the culture at first, but the fruit-bodies subsequently formed showed what seemed to be a normal development (Pl. XXIII G, Fig. 4). The spores were formed upon a fertile layer within a minute lens-shaped cavity just beneath the periderm. These locules measured .5–1 mm. in diameter and .1–.2 mm. in height. The conidiophores arose from a stromatic tissue (Pl. XXIII G, Fig. 5) more or less fully developed, at the base of the cavity, and measured 20–26 $\times$ 2 μ. This fertile tissue was arched over by the periderm which bore only a few stray conidiophores and spores on its interior surface. The cavity opened by a pore to the exterior. The spores (Pl. XXIII G, Fig. 6) abstricted from the tips of the conidiophores were long-fusoid to cylindrical, granular hyaline, and measured 31–45 $\times$ 4–5 μ. They were one-celled when young, but became one- or sometimes three-septate at maturity; these septa were very faint and often obscured by the numerous oil-globules.

This imperfect stage would probably fall in the form genus Septomyxa. So far as can be ascertained, this connection with *Diaporthe furfuracea* has not before been made.

DIAPORTHE ALBO-VELATA (B. & C.) Sacc.

Perithecia

The stromata of the perfect stage of *Diaporthe albo-velata* (B. & C.) Sacc. on *Rhus glabra* L. appear as scattered circular pustules .3–1 mm. in diameter. They are erumpent through the periderm as a compact fascicle of cylindrical ostioles, which emerge through a whitish disc which is almost obliterated by them. The ostioles are covered with a white pulverulent substance, so that the black conical punctate tip appears as a black dot. At maturity the ostioles are long-cylindrical, often somewhat divergent, and later become dirty black. In vertical section (Pl. XXIII H, Fig. 1) the spherical or slightly flattened-oval perithecia, which measure 250–350 $\times$ 250–300 μ, are seen to be buried in the very slightly altered bark tissues, and extend

nearly to the wood surface. The walls are coriaceous, 13–18 μ in thickness, and the necks are long and rather thick, penetrating a stromatic cap which forms the disc, and then elongated to form the cylindrical ostioles. The asci (Pl. XXIII H, Fig. 2) are clavate, and measure 52–65 × 5–8 μ. The spores (Pl. XXIII H, Fig. 3) are biseriate, fusoid, hyaline, two-celled, constricted at the septum, with many oil-drops, and, when young, with a small evanescent appendage, 2–3 μ long, at each end. They measure 14–18 × 2.5–3 μ.

Saccardo separates two uniseptate forms as *Diaporthe albo-velata* B. & C., with spores 20 × 4 μ, and *Diaporthe stilbostoma* (Cke.) Sacc., with spores 17–18 μ long, and one three-septate form as *Calospora aculeans* (Schw.). Sacc. Ellis (3) unites all three of these forms under *Cryptospora aculeans* (Schw.), and points out that the two extra septa in *Calospora aculeans* are pseudo-septa, being merely dividing lines between two adjacent centers or "nuclei," as he calls them. This view of Ellis's seems very likely. The species would then stand as *Diaporthe albo-velata* (Schw.) Sacc.

Pycnidia

On November 15, 1922, a suspension of ascospores of *Diaporthe albo-velata* from perithecia on twigs of *Rhus glabra* L. was sprayed onto Leonian's agar. On November 16, twenty hours later, the spores were found germinating. Transfers to plain oatmeal and beech-oatmeal agars produced a whitish to yellowish-brown, granular to fibrous, superficial growth, and in eight to ten days began to produce a black stromatic line just beneath the surface of the agar. About December 1 hemispherical raised areas of an olive-brown color began to appear in all of the cultures. These cushions remained pulvinate on the moister portions of the agar, but when examined some months later (March 5, 1923), there were found on the dried portions of the agar long stout cylindrical formations. These stromatic formations were found to be made up largely of masses of elliptical light-brown spores mixed in among a sparse growth of brownish hyphae, from which they were abstricted. The entire mass was

surrounded by a felty layer of the same hyphae. The more cylindrical type of stroma was composed of loosely interwoven, brownish hyphae and contained no spores. From later results from twig cultures these formations were concluded to be abortive.

On December 6, 1922, several sterilized twigs of *Tilia americana* L. were inoculated with mycelium from single spore cultures of *D. albo-velata*. The first formations at the point of inoculation, when the culture still contained a high moisture content, were spherical stromatic ones as obtained in culture. On January 12, 1923, one of these cultures, which was in a drier condition, suddenly produced numerous long, (1–2 mm.) slender, black, cylindrical structures (Pl. XXIII H, Fig. 4) which soon became capped with a black spherical mass. These sporodochia, as they proved to be, were composed of a long cylindrical stalk of tightly interwoven, more or less parallel, brownish hyphae, which at its tip cut off numerous brownish spores from the tips of the hyphae (Pl. XXIII H, Fig. 5). These were cut off in such numbers as to form the black spherical mass mentioned above. The tip of the stalk was sometimes slightly branched, but this was obscured within the mass of spores and showed only upon microscopical examination. The spores (Pl. XXIII H, Fig. 6) were oval or slightly fusoid, dilute blackish hyaline, one-celled, and measured $6–9 \times 2.5–3\ \mu$. All stages and variations of these structures from the flat pulvinate stromata on agar cultures and the thick, cylindrical stromata and sporodochia with a stromatic base, to the true sporodochia, were produced; the various forms seemed dependent largely on the moisture content. This imperfect stage has also previously been found associated in nature with *Diaporthe albo-velata* on Rhus twigs, and is probably *Sporocybe Rhois* (B. & C.) Sacc., which occurs on Rhus and greatly resembles the form obtained in culture.

In conclusion the writer wishes to express his thanks to Dr. C. H. Kauffman for his helpful suggestions throughout the work and for his critical reading of the manuscript.

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EXPLANATION OF PLATES

PLATE XXI

A. *Diaporthe oncostoma* (Duby) Fck.
- Fig. 1. Vertical section of perithecial stroma.
- Fig. 2. Vertical section of pycnidial stroma on *Robinia pseudo-acacia.*
- Fig. 3. Vertical section of stromatic pycnidial formation on oatmeal agar.
- Fig. 4. Detail of section through locule wall and conidiophore layer.
- Fig. 5. Ascospores.
- Fig. 6. Ascus with ascospores.
- Fig. 7. Hamate type of conidia.
- Fig. 8. Fusoid type of conidia.

B. *Quaternaria Persoonii* (Pers.) Tul.
- Fig. 1. Vertical section of perithecial stromata.
- Fig. 2. Ascus with ascospores.
- Fig. 3. Ascospores.
- Fig. 4. Vertical section of imperfect stage on *Fagus grandifolia.*
- Fig. 5. Detail of conidiophore layer and basal tissues.
- Fig. 6. Conidia.

C. *Diatrype virescens* (Schw.) Berk.
- Fig. 1. Vertical section of perithecial stromata.
- Fig. 2. Ascus with ascospores.
- Fig. 3. Ascospores.
- Fig. 4. Type of locules formed on beech oatmeal agar.

PLATE XXII

C. *Diatrype virescens* (Schw.) Berk.
- Fig. 5. Vertical section of imperfect stage on *Fagus grandifolia* as formed under low moisture conditions.
- Fig. 6. Tubercularia-like formation of imperfect stage on Fagus under high moisture conditions.
- Fig. 7. Detail of conidiophore layer.
- Fig. 8. Conidia.

D. *Diatrypella Frostii* Pk.
- Fig. 1. Vertical section of perithecial stromata.
- Fig. 2. Ascus and ascospores.
- Fig. 3. Ascospores.
- Fig. 4. Vertical section of imperfect stage on *Fagus grandifolia* in culture.
- Fig. 5. Detail of conidiophore layer and basal tissues.
- Fig. 6. Conidia.

E. *Valsaria exasperans* (Gerard) E. & E.
- Fig. 1. Vertical section of perithecial stromata.
- Fig. 2. Ascus with ascospores.
- Fig. 3. Ascospores.

F. *Valsaria insitiva* Ces. & De Not.
- Fig. 1. Vertical section of perithecial stroma.

PLATE XXIII

F. *Valsaria insitiva* Ces. & De Not.
- Fig. 2. Vertical section of imperfect stage on *Acer saccharinum.*
- Fig. 3. Detail of walls of locules and conidiophore layer.
- Fig. 4. Conidia.

G. *Diaporthe furfuracea* (Fr.) E. & E.
- Fig. 1. Vertical section of perithecial stromata.
- Fig. 2. Ascus with ascospores.
- Fig. 3. Ascospores.
- Fig. 4. Vertical section of imperfect stage on *Tilia americana* from culture.
- Fig. 5. Detail of conidiophore layer and basal tissues.
- Fig. 6. Conidia.

H. *Diaporthe albo-velata* (B. & C.) Sacc.
- Fig. 1. Vertical section of perithecial stroma.
- Fig. 2. Ascus with ascospores.
- Fig. 3. Ascospores.
- Fig. 4. Sporodochia of imperfect stage on *Tilia americana* from culture.
- Fig. 5. Detail of spore-bearing hyphae.
- Fig. 6. Conidia.

PLATE XXI

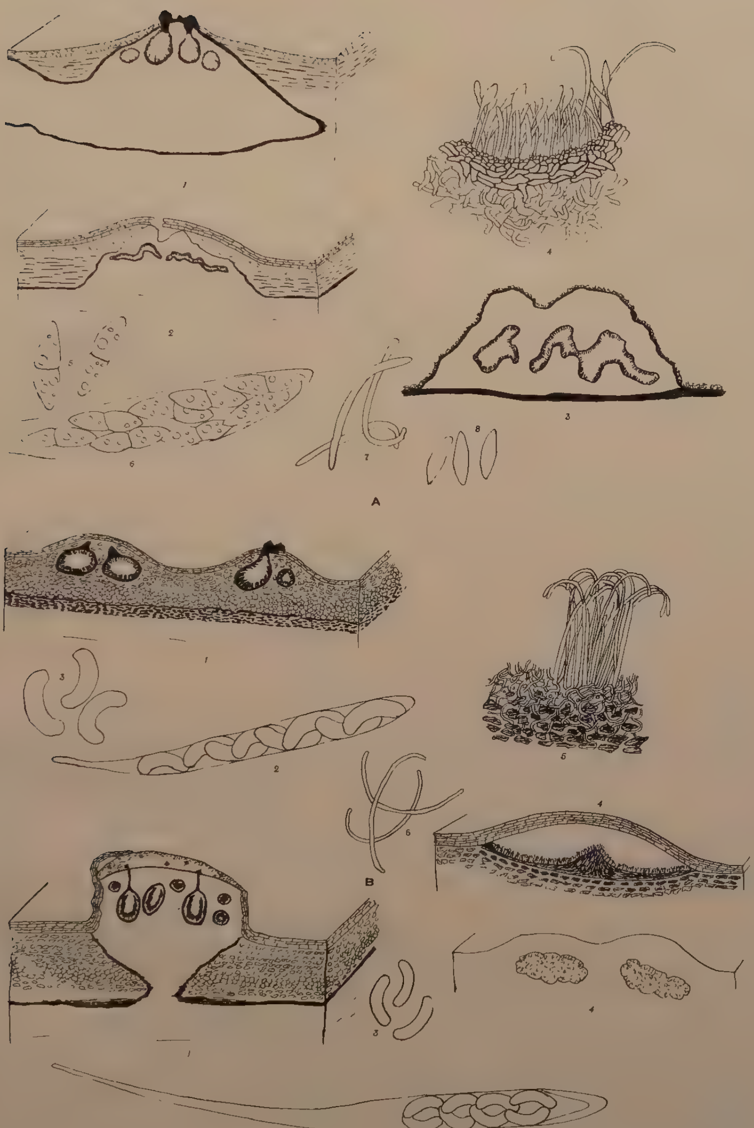


PLATE XXII

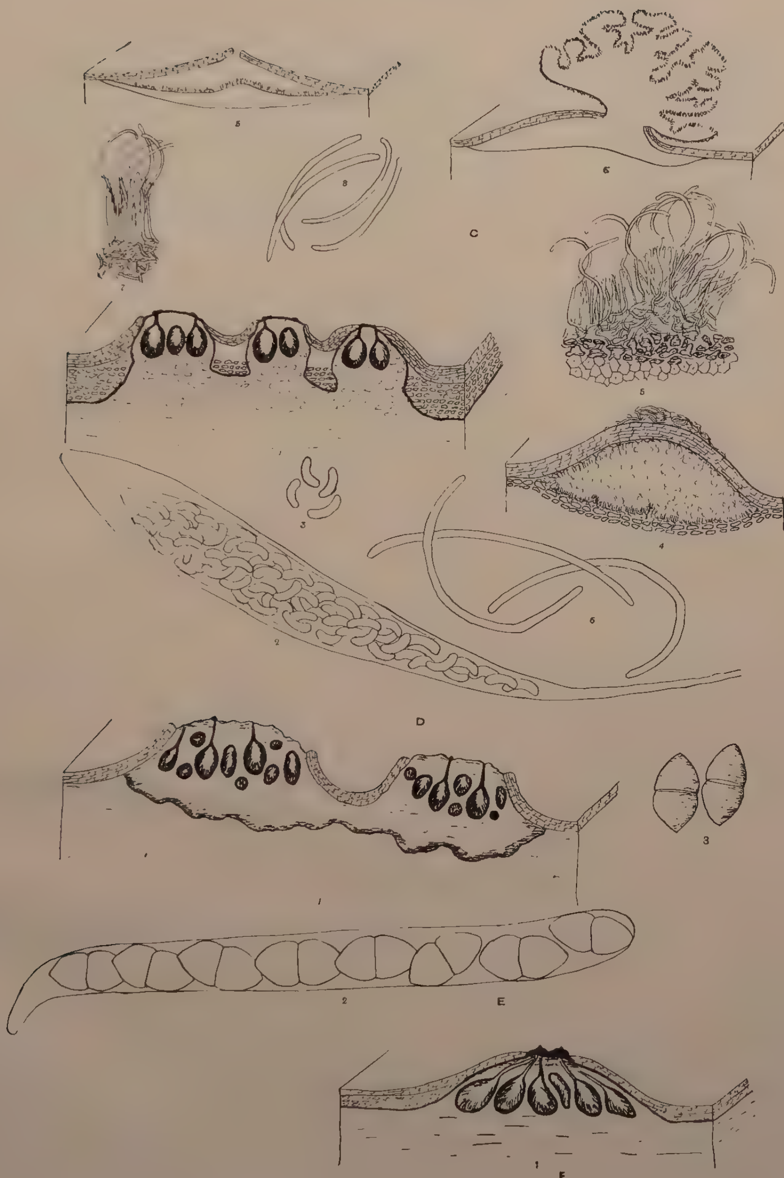
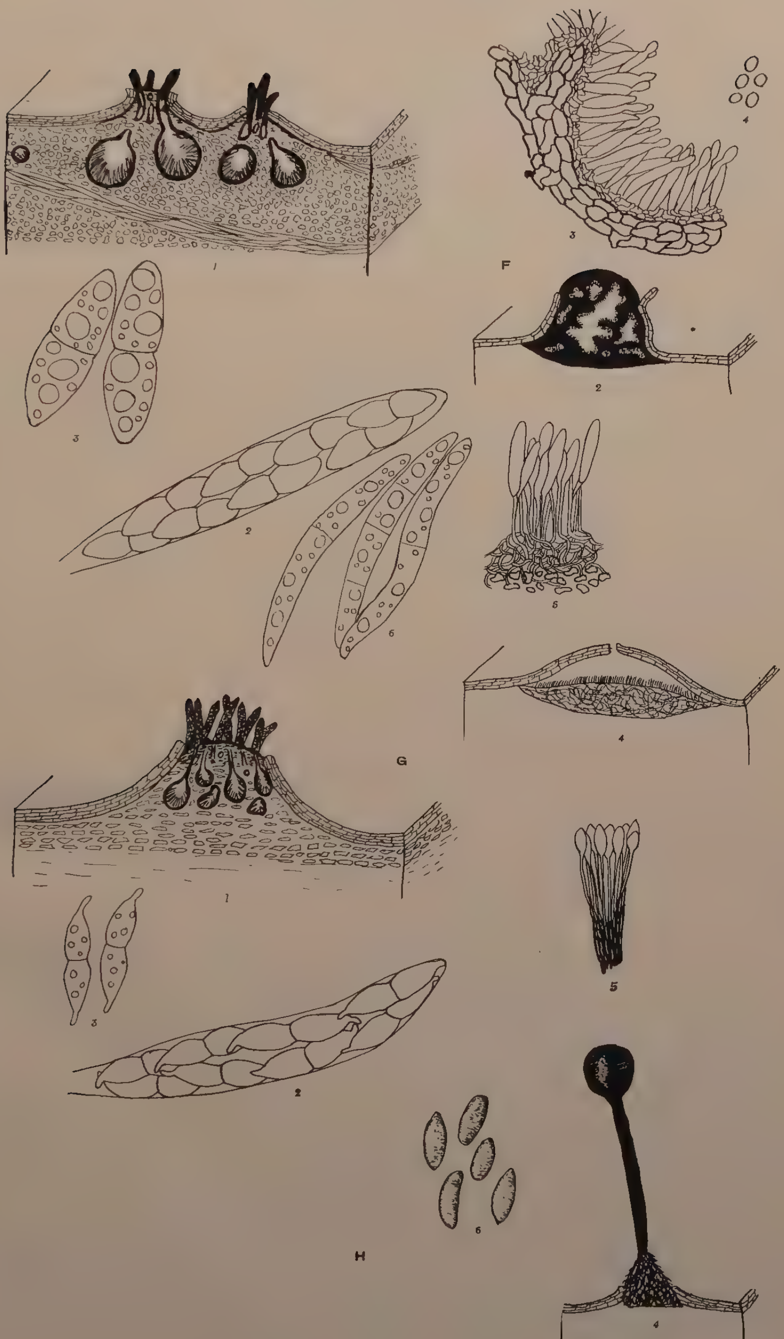


PLATE XXIII



SOME ASPECTS OF EQUIPMENT OBLIGATIONS

KENNETH DUNCAN

There is no other class of railroad securities which in recent years has increased more rapidly in amount or which possesses a greater number of features of extraordinary interest than equipment obligations. Yet in spite of the fact that these securities now aggregate nearly a billion dollars in par value and constitute over five per cent of the total funded debt of American railroads, economists and bankers are probably less familiar with them than with any other important group of corporate obligations. It will be the purpose of this paper to describe some of the unique characteristics of equipment obligations, to point out the remarkable development in their use, and to analyze briefly their financial merits.

I. NATURE OF EQUIPMENT OBLIGATIONS

In general, equipment obligations consist of bonds, notes, or certificates the immediate or ultimate security of which is essentially a lien upon specific lots of railway rolling stock and equipment. They belong to that broad group of securities known as purchase money obligations. They arose originally to meet the needs of indigent railroads for borrowing capital under most economical terms in order to obtain essential equipment. They are peculiarly an American product, and are practically unknown except in the United States and Canada. At first of but slight importance, they have come to play a significant rôle in railroad finance and to represent the most generally accepted method by which additional equipment is financed.

While in essence equipment obligations are a species of mortgage bond, the special character of the security and the

peculiar legal forms of the contracts under which they are issued warrant us in placing them in a distinct category. They are unique among corporate securities in several particulars. Although based on what seems to be the most temporary and insubstantial kind of security, rolling stock, equipment obligations are remarkably well-secured. While the basic contract is intended to be in effect a mortgage lien, generally great care is taken to prepare it so that it cannot be so construed at law. Unlike other railroad securities, equipment obligations mature serially over a comparatively short term. Frequently the obligation is not that of the railroad company which is ostensibly the borrower, and indeed the obligations may not appear in the balance sheet of the railroad company at all. In form, they may be no more than shares of stock or collateral trust issues behind which lies only a contract, and yet they are often rated "better than first mortgage bonds."

In spite of the existence of prior mortgages of the most explicit and all-inclusive character, equipment obligations are usually given a senior rank at law. In receiverships and reorganizations, the acid tests for all corporate securities, they have fared better than first mortgage bonds or even receivers' certificates. The legal strength of equipment obligations has been established indisputably by decisions in the highest courts of the country, and has further been confirmed by statutory provisions in every state in the Union. Although almost never listed on stock exchanges, equipment obligations enjoy a ready and stable market. No other railroad securities reflect to a lesser extent the individual financial fortunes of the company behind them, and among no other classes of corporate securities have even temporary defaults been so rare.

II. OCCASION FOR THE USE OF EQUIPMENT OBLIGATIONS

We may best explain equipment obligations by considering briefly the occasion for their use. A railroad contemplating the acquisition of new equipment may adopt one of several alternative plans for financing the purchase. The railroad might pay

for the equipment in cash for the full cost, but ordinarily the amount is so large as to make such a procedure impracticable. A road financially embarrassed, whose need for additional equipment might be most imperative, would be unable to obtain the equipment at all, unless credit could be extended. Another plan might be for the railroad to buy the equipment on the strength of its general credit promise, in the same manner as current supplies and labor are acquired. While this plan may be practicable for railroads enjoying a high credit standing and able to make an early settlement of the debt, in other cases it presents serious difficulties. Manufacturers of equipment are unwilling to extend credit for as long a term and for as large an amount as the railroad may desire, and could be induced to do so only by the payment of prohibitive interest rates. Accordingly, the most feasible arrangement is usually one that will allow the seller a lien on the specific lot of equipment sold.

At first thought, one might suppose that a chattel mortgage lien on the property would offer the simplest and most desirable basis for the transaction. In practice, however, this plan is rarely used. This is because nearly all railroads have prior general mortgages outstanding which cover all after-acquired property of the railroad company. As title passes as soon as a sale is made, the equipment intended to be covered by a chattel mortgage would be subject at once to the prior lien of the general blanket mortgage, and the chattel mortgage lien would be of inferior rank. Hence the use of the chattel mortgage is practicable only if the railroad company is free to give such a first lien — which few railroads are able to do — or if the mortgage can be attached to the equipment before its acquisition by the railroad. Moreover, the feasibility of using chattel mortgages is greatly circumscribed by illiberal statutory provisions with respect to recording in various jurisdictions.

In order to accomplish the separate financing of the equipment on economical terms, and to give the seller a direct lien on the property sold, in spite of the after-acquired property clause in a prior mortgage, business and legal ingenuity has devised the plan of using a lease or a conditional sale as the

basis for the transaction. Either form of contract will avail to prevent the passage of title to the purchasing railroad company until full payment has been made, and will furnish a satisfactory basis on which equipment obligations may be issued.

III. THE LEASE PLAN

In the earlier stages of the development of equipment obligations, the lease was employed almost exclusively. The reason was that in certain important jurisdictions, notably Illinois and Pennsylvania, a conditional sale of chattel property, while valid between the parties concerned, could not be enforced against third parties, such as judgment creditors, purchasers for value without notice, and mortgagees. The conditional sale gave the seller inadequate protection. But if the agreement were drawn as a lease and contained a clause giving the lessee an option of purchase, such a contract was held by these courts to be of complete validity, even against third parties.

The validity of the agreement was upheld even though the rental payments stipulated in the so-called lease were obviously merely installments of purchase price, and even though it was agreed that a bill of sale should be executed without further consideration when the last rental payment had been met. Such an arrangement was clearly a subterfuge, but it stood the test in the courts of Pennsylvania and Illinois, although in most other jurisdictions courts at first were inclined to frown upon the device and to give it not greater effect than if it had been a conditional sale or a chattel mortgage. It is, of course, needless to say that nowadays the device has come to be so universally used and so thoroughly respected in the courts that there is no longer any suggestion of "subterfuge" or irregularity attaching to such transactions. The plan is now a practical business expedient, based on a legitimate legal fiction, and is used alike by roads of high and low credit standing.

Originally the lease was executed in connection with a car trust, which consisted of a special association created for the purpose of acquiring the equipment and leasing it to the railroad

company at annual rentals sufficient to cover interest on the debt, expenses of the trust, and installments of cost, so that at the end of about ten years the railroad should have paid a total amount equal to the cost. The agreement then provided that the railroad company was to become the owner of the equipment, either without further payment, or on payment of a purely nominal sum. A trustee was appointed who acted on behalf of the car trust association in financial and legal relationships with the railroad.

The plan comprehended essentially two agreements: (a) the *lease contract* with the railroad, and (b) a *trust agreement*, the terms of which provided for the deposit of the lease with a trustee or trust association, who issued against it a series of certificates declaring that the holder was entitled to a beneficial interest in the trust and a proportionate share in the moneys receivable from the railroad on account of the lease. The trustee was empowered to retake and sell the equipment on behalf of the certificate holders in event of default in the payment of rentals.

In most respects, the procedure just outlined is followed today in connection with equipment obligations issued under what is called the Philadelphia lease plan. At present, however, the formality of a car trust association is dispensed with, the certificates are issued by the trustee to contributors to a trust fund, and the railroad company usually adds its guarantee directly on the certificates.

The early use of the lease and car trust arrangement gave the Philadelphia plan equipment certificates the momentum of an early start, and has endowed this species of obligations with such prestige and has inspired investors with such confidence that equipment obligations issued under other plans, equally secure and much less complicated, have been quite generally viewed with a touch of suspicion.

IV. THE CONDITIONAL SALE PLAN

During the eighties and nineties, however, practically every state in the United States enacted laws regulating the condi-

tional sale of railroad rolling stock and equipment, so that now the original disability of the conditional sale to secure complete protection to the immediate parties no longer obtains. In more recent years, therefore, the issue of straight equipment bonds or notes, based directly on the pledge of a contract of conditional sale, is being resorted to more frequently. Equipment securities are more and more being issued in the form of direct obligations of the railroad, and the lease idea, which many courts have been manifestly reluctant to recognize as a lease, has tended to disappear. Indeed, except with a few important roads, such as the Pennsylvania, the Baltimore and Ohio, the Illinois Central, and a few others, the lease plan is now rarely used, and the simple equipment bond or note is more common. Popular impression to the contrary it is immaterial whether the basic contract be a lease or a conditional sale, but it is of utmost importance that the provisions of the various state statutes requiring that such contracts be recorded should be scrupulously observed.

V. THE EXTRAORDINARY GROWTH OF EQUIPMENT OBLIGATIONS

The extraordinary success with which equipment obligations have been employed is shown by the huge amount of such securities that has been issued. By 1890, the total of equipment obligations outstanding, as reported by the railroads to the Interstate Commerce Commission, had reached approximately fifty millions of dollars. The decade following saw but little increase, but with the period of reviving business and general prosperity that characterized the first years of the twentieth century, there was a surprisingly large amount of new securities of this type placed on the market. The obligations outstanding in 1905 were more than triple those outstanding in 1900, and ten years later the total was almost half a billion dollars. During the war years from 1915 to 1920, but little new equipment financing took place, and, as the maturities exceeded new emissions, the aggregate of obligations outstanding declined, until in 1920 the flood of new issues in post-war financing by

the railroads and others, augmented by the extraordinary equipment trusts of that year in which the Government assisted, brought the total to a new high mark of approximately three quarters of a billion dollars. Appreciable amounts of equipment obligations have also been issued by switching and terminal companies, street and interurban railways, refrigerator and tank car companies, coal and steel companies and the like.

Not only have equipment obligations been increasing absolutely in amount, but they have come to occupy a place of increasing relative importance. An examination of the statistics discloses the fact that the ratio which the amount of equipment obligations outstanding bears to total funded debt of American railroads is a steadily increasing one, especially since 1900. In the nineties equipment obligations comprised about 1 per cent of the funded debt, but in 1920 about 6 per cent.

VI. FINANCIAL MERITS OF EQUIPMENT OBLIGATIONS

It has been suggested that, so far as the purchasing company is concerned, the advantage in the use of equipment obligations is chiefly that they make possible an independent financing of new equipment at an economical cost, irrespective of the financial status of the company, and that payments for the equipment can be made by regular installments over a number of years. The remarkably low rate of interest equipment securities bear — ordinarily but little if any greater than that commanded by premier mortgage securities of the same company — indicates the saving in interest costs which their use makes possible.

From the point of view of the investor, the merit of equipment obligations lies mainly in the safety of principal. They possess unimpeachable legal security; and if equipment contracts have been executed and recorded with careful regard for existing laws, there is no question but that the holders of the obligations, in case of default, may proceed according to the terms of the underlying agreement to retake and sell the pledged equipment. Such a procedure is quite feasible. On the other

hand, it is only too well known that, in the case of a first mortgage lien on the real property of a railroad, such as rights of way, terminals, bridges, and the like, it may frequently be quite impracticable to exercise the legal right of foreclosure and sale, that the lien of the mortgagees may have been emasculated through receivers' certificates issued under order of a court prior to foreclosure, and that the buyers of the real property of a bankrupt road must often be the creditors themselves. In contrast to this, equipment pledged under the usual forms of equipment agreements cannot be affected by the action of other creditors or of the receiver, inasmuch as the railroad holds no title. Moreover, since railroad rolling stock consists of standard units of movable equipment that has a ready market in a field in which competitive conditions prevail, the separate disposal of equipment is an easy matter.

As long as the equipment pledged is of greater value than the obligations outstanding thereon, the safety of the principal is assured. A railroad must have equipment in order to care for its business. The remedy of equipment note holders in event of default is immediate and complete. Not only would the consequences of default inure to the ultimate financial loss of the railroad company, but what is probably more serious, the deprivation of a considerable portion of its equipment might leave it crippled and helpless to continue its ordinary traffic operations. It is this indispensable character of railroad equipment, the inescapable necessity for its use, coupled with the legal right and practicability of its removal from the railroad's premises, that constitutes for the equipment creditor the strongest guarantee that default will not occur.

VII. ADEQUACY OF SECURITY BEHIND EQUIPMENT OBLIGATIONS

It is quite necessary that the equity of the equipment note holder be adequate, else it may prove more profitable for the railroad to relinquish the pledged equipment than to continue its payments. Unlike most property subjected to a lien for the purpose of borrowing funds, railroad equipment depreciates

rapidly, frequently needs extensive repairs, is occasionally lost or destroyed, in the course of its use strays from the premises of the obligor corporation, and sometimes suffers decline in value due to obsolescence or inadequacy. Prices of equipment may move downward, because of lower costs of production or changes in the price level. All these considerations must be weighed by the prospective note holder desirous of maximum security. From his viewpoint, the terms of the basic agreements must be so drawn, that even under the most extreme and adverse situations, the notes outstanding will not be greater in amount than the liquidation value of the equipment.

This protection is obtained by one or more of the following three methods: (1) an initial cash payment, usually 10 to 25 per cent of the cost of the equipment, which is made by the railroad company at the time the original purchase agreement is signed and which constitutes the initial margin of safety for the equipment obligations issued for the balance of the cost; (2) the retirement of the issue of obligations by serial maturities, or by periodic payments to a sinking fund; and (3), in certain extraordinary cases, the subordination of certain notes in an issue to others of the same issue. In addition, the trust agreement usually stipulates that the railroad company shall maintain the property in good repair, shall replace or deposit moneys for all equipment lost or destroyed, and shall maintain insurance on the equipment for such contingencies as are ordinarily capable of being insured against.

Reasonable caution requires that the cost of the equipment should not be excessive, that payments be liberal, that the term be comparatively short, that maintenance and repairs be attended to, and that regular reports thereon be forthcoming to the trustee. The amount of the initial cash payment should be large enough to cover the greatest possible depreciation for such period until serial payments begin. Moreover, the amount of serial payments, either of maturing notes or of payments into a sinking fund, as the case may be, should thenceforth be no less than the greatest possible periodic diminutions in the value of the equipment. Ordinarily, these serial payments will pile

up faster than depreciation accrues, and when this is the case, the notes of longer term come to possess even greater security than earlier maturities of the same issue. It should be observed however, that this seeming advantage possessed by notes of late maturity may be nullified by an unforeseen long-term decline in prices of equipment.

The rate of depreciation used in calculating the value of the equipment from the viewpoint of complete security to holders of equipment obligations, does not necessarily coincide with the rate used by the railroad in its formal accounting. The railroad maintains its allowance for depreciation account in order to recognize regularly charges to expense on account of the eventual scrapping of the equipment. The primary bases on which it fixes its rate of depreciation are the service life, original cost, and residual value of the equipment. It need not pay attention, so far as its depreciation accounts are concerned, to fluctuations in the market value of the property nor to potential sacrifice sale values.

On the other hand, the value in which the holders of equipment obligations are interested is the liquidation value, or the possible sale value of the property as second-hand equipment at future times, what the specific property will bring at a sacrifice sale as used equipment under whatever conditions of market prosperity or depression that may then obtain. In fact, strictly speaking, no uniform "rate" would be manifest at all. In effect, note holders must make a series of intelligent guesses, based on past experience as to service life, residual value, and market fluctuations of railroad equipment of like character, and be reasonably sure that the initial payment and subsequent serial retirements of obligations by the railroad company are ample to keep the notes outstanding at any time well under these estimated figures. Liquidation value, particularly in the earlier years of service life, will be considerably less than ordinary book value (cost less a normal depreciation of, say, five per cent per annum). Not infrequently, however, in bankers' circulars descriptive of equipment obligations, extravagant claims are made for the security behind notes of later maturities,

by computing the margin of safety on ordinary book values, or, worse yet, by ignoring depreciation altogether.

The fact that the security for equipment obligations rests so completely in the worth of the specific equipment itself justifies the generally accepted notion that the general credit of the issuing company is of but secondary importance and the value of the equipment is of prime importance. This is shown empirically by the fact that during the winter of 1922–23 the equipment obligations of the Denver and Rio Grande, a railroad some of whose bonds are in default and whose general credit promise is of little value, are selling on a 5.70 per cent basis, which is less than 1 per cent higher than the yield obtainable on equipment obligations reinforced by the general credit of the strongest of roads, such as the Pennsylvania, the Atchison, the Chicago and Northwestern, and others.

VIII. SOME DOUBTFUL TENDENCIES

In recent years, there has been a marked tendency toward small or no initial cash payments and toward fifteen-year terms in equipment issues. While prior to 1918 the most usual maximum term was ten years, since then fifteen-year terms have been predominant. One cannot but regard these tendencies with some misgiving and regret. It is probable, to be sure, that the more durable character of modern steel equipment will tend to counterbalance this contingency to some extent, and that roads, in practically all cases, will continue to make prompt and regular payments, certainly as long as solvent, and even if insolvent, as long as the unmatured obligations do not exceed the cost of reproducing or replacing the pledged equipment with other equipment of equivalent service value. But it cannot be denied that in some respects these more recent equipment issues do not afford as great security of principal as the time-honored issues in which the initial payment was not less than 20 per cent of actual cost of the property and in which the maximum term did not exceed ten years.

IX. POSSIBLE EXTENSIONS IN THE USE OF EQUIPMENT OBLIGATIONS

The suggestion has naturally often been made that the equipment trust device might be susceptible of more extensive application, and that the acquisition of essential units of machinery and of standard manufacturing equipment might well be financed through the issue of equipment securities. So far as the present writer is aware, however, there is no important issue of equipment obligations in which the tangible security has not been composed of railroad rolling stock or marine equipment.

There are, moreover, certain inherent difficulties that appear to prevent the extensive application of the equipment trust principle outside the field of transportation finance, and make it highly improbable that equipment obligations will become of importance in financing industrial equipment. First of all, there are no kinds of industrial equipment of semi-permanent character which are bought and sold in lots large enough to warrant the issue of a series of securities thereon addressed to the general investment market. Besides, manufacturing equipment is usually of such a highly specialized character and is often subject to such a heavy depreciation due to deterioration or obsolescence as to have a very conjectural liquidation value. Even though physically capable of a fairly long service life, it could hardly be regarded as a safe security for any but extremely short-term obligations.

Furthermore, in the case of railroad rolling stock, the very nature of the use to which it is put scatters the various units and renders the danger of catastrophic loss negligible, while there are few forms of manufacturing equipment or machinery which are not concentrated in the same or a few plants, greatly magnifying the risk attendant on a disaster. Railroad and marine equipment, because it consists of standardized units, commands a ready resale market, and its physical character is such that it can easily, cheaply, and expeditiously be moved in case recaption is necessary. No other property possesses these advantages to the same degree. Another reason for the absence

of equipment obligations among industrial corporations is that there is not the compelling necessity for the use of the device to avoid the consequences of after-acquired property clauses in general mortgages. Blanket mortgages are much less common among industrial companies than among transportation companies. We may safely conclude, therefore, that in spite of the remarkable success of equipment obligations in the field of railroad finance, they are not likely to be employed to any considerable extent in other financing.

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THE PRESENCE OF CATARACT STRATA IN MICHIGAN SUPPORTED BY FOSSIL EVIDENCE

G. M. EHLERS

So far as known, no exposures of Cataract strata, which are regarded as being of Lower Silurian or Oswegan age, occur in Michigan. Cataract strata are probably present in the eastern part of the Northern Peninsula, and would be exposed except for a covering of glacial deposits. The outcrops nearest to Michigan occur on Manitoulin Island, Ontario; other exposures are present at several places along the Niagara escarpment between Manitoulin Island and Niagara Falls.

In recent years, certain strata, penetrated in drilling deep wells in Michigan, have been assigned to the Cataract by the Michigan Geological and Biological Survey, because they have the same lithological character as the rocks of this formation and occupy a similar stratigraphic position. The Cataract age of these unexposed strata, based on similarity in lithological character and stratigraphic position, is, however, open to question, because a younger or older age than the Cataract may very readily be postulated for these beds.

Fortunately, fossils, which were found in drillings brought to the surface in sinking the Henry Ford well at Dearborn and well Number 9 of the Diamond Crystal Salt Company at St. Clair, indicate beyond question the presence of Cataract strata in Michigan. These fossils, which were kindly identified by Dr. E. O. Ulrich of the United States Geological Survey, are noted in the tables below. The kind of rock and depth in feet below the surface, from which they were obtained, and their stratigraphic occurrence in other regions are also indicated.

An examination of these tables shows that *Sceptropora*

fustiformis Ulrich and *Dalmanella aff. eugeniensis* Williams have thus far been found only in the Cataract and that *Phaenopora expansa* Hall & Whitfield has been reported from the Brassfield, a very close correlate with the Cataract in time. The other

TABLE I

Fossils from Henry Ford Well, at Dearborn, Michigan

Names of Species	Depth and Rock Matrix	Stratigraphic Occurrence
Bryozoa		
Hallopora magnopora (Foerste) (small variety)	2415′ and 2420′ Greenish-gray shale	Brassfield (Ohio) Rochester (Ontario)
Helopora fragilis Hall	2415′ and 2420′ Greenish-gray shale	Cataract (New York and Ontario) Lower Clinton (New York)
Phaenopora constellata Hall	2415′ Greenish-gray shale	Clinton (New York) Cataract (Ontario)
Phaenopora ensiformis Hall	2415′ Greenish-gray shale	Cataract (Ontario) Rochester (New York and Ontario) Osgood (Indiana) Brassfield (Ohio) Ellis Bay and Becsie River (Anticosti) Borkholm drift (Gotland)
Phaenopara expansa Hall & Whitfield	2405′ Greenish-gray shale	Brassfield (Ohio)
Brachiopoda		
Dalmanella aff. eugeniensis Williams	2415′ and 2420′ Greenish-gray shale	Cataract (Ontario)

species, which, with the exception of *Phaenopora constellata* Hall, were first noted as occurring either in the Cataract or Brassfield, seem to have a slightly greater stratigraphic range. Considered as a group, however, the fossils represent a typical Cataract assemblage. They indicate beyond question that the greenish-gray shale penetrated in the Ford well between depths

of 2405 and 2420 feet and the red and greenish-gray shales encountered in well Number 9 of the Diamond Crystal Salt Company between depths of 2770 and 2800 feet are of Cataract

TABLE II

FOSSILS FROM WELL NUMBER 9,
DIAMOND CRYSTAL SALT COMPANY AT ST. CLAIR, MICHIGAN

Names of Species	Depth and Rock Matrix	Stratigraphic Occurrence
Bryozoa		
Hallopora magnopora (Foerste)	2800′ Greenish-gray shale	Brassfield (Ohio) Rochester (Ontario)
Helopora fragilis Hall	2785′ Red shale	Cataract (New York and Ontario) Lower Clinton New York
Helopara fragilis Hall	2800′ Greenish-gray shale	Same as above
Sceptropora fustiformis Ulrich	2775′ Greenish-gray shale	Cataract (Ontario)
cf. *Sceptropora fustiformis* Ulrich	2770′ Greenish-gray shale	Same as above
Phaenopora expansa Hall & Whitfield	2785′ Red shale	Brassfield (Ohio)

age. Furthermore, these fossils lend support to Mr. R. A. Smith's assignment to the Cataract of 140 feet of strata, penetrated in the Ford well [1] between depths of 2320 and 2460 feet and 170 feet of rock, encountered in well Number 9 of the Diamond Crystal Salt Company [2] between depths of 2700 and 2870 feet.

UNIVERSITY OF MICHIGAN

[1] The description of the Cataract strata of the Ford well is given by Mr. Smith in Figure 7, opposite page 248, of *Publication 24, Geological veries 20, Michigan Geological and Biological Survey*, 1917.

[2] The record of this well has not been published. Mr. Smith's provisional record, which the writer was given permission to examine, is on file in the office of the Geological Division of the Department of Conservation at Lansing, Michigan.

A DRILL CORE SECTION OF THE SALINA BELOW THE SALT BED OF THE DETROIT ROCK SALT COMPANY MINE

JOHN W. VANDERWILT

THE Salina formation of upper Silurian age in Michigan consists of beds of salt, shale, dolomite and anhydrite. The salt beds are the chief source of salt in Michigan.

At Oakwood, Detroit, Michigan, a bed of salt 30 feet in thickness, whose base is 1140 feet below the surface, is mined by the Detroit Rock Salt Company. A geological section above and below this salt bed was published by Albert H. Fay [1] in 1911. A columnar section based on the geological section by Fay was subsequently published by Prof. W. H. Sherzer.[2] These sections indicate that the Salina above the salt bed now being mined consists of 263 feet of alternating beds of salt and dolomite. It is interesting to note that the salt bed being exploited is the thickest single bed of salt of this part of the Salina section.

The Detroit Rock Salt Company, by means of a diamond drill, has penetrated the Salina to a depth of 558 feet below this salt bed, from which the salt is now being mined. Through the kindness of Mr. G. W. Hain, manager of the company, the writer has received permission to study the drill core. The writer's interpretation of this core is embodied in the columnar

[1] Fay, Albert H. *Shaft of Detroit Salt Company. Eng. and Min. Jour.*, 91, 565. 1911.

[2] Sherzer, W. H. *Geological Report on Wayne County. Mich. Geol. and Biol. Surv., Pub.* 12, *Geol. Ser.* 9, Fig. 21. 1911.

Sherzer, W. H. *Detroit Folio, No.* 205. *U. S. Geol. Surv.*, Fig. 19. 1917.

section shown in Figure 6. At this time the writer wishes to acknowledge his appreciation of the assistance of Mr. G. M. Ehlers in carrying out this work.

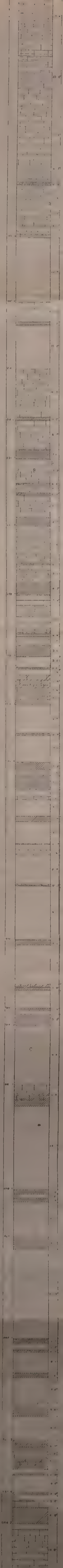
The quantity of salt, dolomite and anhydrite in this section is of considerable interest. If the very few thin beds of shale of the section are included with the dolomite, a considerable part of which is argillaceous, the section is seen to consist of 268 feet of salt, 219 feet of dolomite and 71 feet of anhydrite. Although salt forms a considerable part of the section, no single bed of salt attains very great thickness.

Mr. Fay is incorrect in showing a bed of salt 369 feet in thickness at the base of his geological section. An examination of the drill core shows beyond question that the material of the upper 263 feet of the supposedly thick bed of salt consists of salt with thin beds of anhydrite and dolomite. This part of the bed occupies a position corresponding to the lower portion of the Upper Salina of the Henry Ford Well[3] at Dearborn. The lower 106 feet of Mr. Fay's supposedly thick bed of salt occupies a position corresponding to the upper part of the Lower Salina of the Henry Ford Well. Since this part of the Salina consists entirely of dolomite, it seems very likely that the lower 106 feet of Mr. Fay's geological section may also be composed of dolomite instead of salt. The facts adduced above prove that Professor Sherzer was correct in stating in his columnar section that the 369 feet of salt would be found to be divided by beds of dolomite.

The section given in Figure 6 is also interesting in showing that most of the beds of anhydrite occur in the lower part of the drill core. This distribution of anhydrite may prove to be of significance to the order of deposition, and more especially in regard to the determination of the conditions under which the Salina formation of Michigan was deposited.

It seems probable that this rather detailed section may serve

[3] The excellent and important section of the Henry Ford Well was published by Mr. R. A. Smith, director of the Michigan Geological and Biological Survey. Smith, R. A. *Deep Well Borings. Mich. Geol. and Biol. Surv. Pub.* 24, *Geol. Ser.* 20, Pt. 3, pp. 247–248, Fig. 7. 1916.



Dolomite, gray to brownish gray, ... [illegible]
(This part of core was found disarranged.)

Dolomite, gray to brownish gray, and with some portions argillaceous

Dolomite, brownish gray and finely crystalline, with [illegible]

Dolomite, brownish gray and finely crystalline, [illegible] toward base

Anhydrite interbedded with dolomite

Dolomite light to dark gray and finely crystalline. Dark portions argillaceous

Dolomite, brownish gray and finely crystalline, with many crystals of dolomite

Dolomite, dark gray, finely crystalline and argillaceous, with anhydrite interbedded near base. Many small veins of salt occur in the lower foot of rock

Salt, colorless to white

Dolomite, gray to brownish gray, very finely crystalline and argillaceous, with anhydrite interbedded and in [illegible] increasing in amount near base. Some salt in small scattered crystals [illegible]

Anhydrite, with some dolomite

Salt, similar to bed *A* above

Dolomite, light gray to brownish gray, very finely crystalline and argillaceous, with some anhydrite in thin bands and in masses and scattered salt crystals and veins. Some veins contain red fibrous salt

Anhydrite, gray

Dolomite, dark gray, very finely crystalline and argillaceous, with scattered masses of anhydrite and veins of red fibrous salt. Toward the base the dolomite and anhydrite are interbedded and the rock grades into the bed below

Anhydrite, interbedded with gray dolomite and containing a few scattered crystals of salt

Dolomite, dark gray, finely crystalline and argillaceous, with anhydrite interbedded and in small masses. Salt occurs as small crystals and veins. The salt of the veins is the red fibrous variety mentioned above

Anhydrite interbedded with dolomite
Dolomite similar to bed *B* above
Anhydrite interbedded with dolomite

Dolomite similar to bed *B* above

Anhydrite and dolomite gray in color, with red fibrous salt in very small scattered veins

Dolomite, similar to bed *B* above

Anhydrite and dolomite gray in color

Anhydrite, gray, with some dolomite

Dolomite, brown, very coarsely crystalline and with interbedded anhydrite

Dolomite, similar to bed *B* above

Anhydrite gray in color
Dolomite, gray and argillaceous, with a vein of red fibrous salt

Anhydrite with [illegible]

Salt, colorless to white, with a few thin bands of anhydrite
Anhydrite
Salt, colorless to white

Anhydrite with interbedded dolomite [illegible] scattered crystals

Dolomite, argillaceous, with interbedded anhydrite

Anhydrite and dolomite, gray in color

Salt, colorless to white, with some thin bands of anhydrite [illegible]

Anhydrite with some salt

Salt, colorless to white, with some thin bands of anhydrite and dolomite

Anhydrite, with a little salt and dolomite
Dolomite, gray, finely [illegible], with anhydrite and [illegible] salt

Anhydrite, with interbedded dolomite and scattered [illegible]

Salt, similar to bed *A* above
Dolomite, gray, with [illegible]

Salt, similar to bed *A* above

Anhydrite, gray, with [illegible]

Salt, similar to bed *A* above

Anhydrite, [illegible] dolomite
Salt, similar to bed *A* above
Dolomite, gray, finely crystalline and argillaceous, alternating with several thin bands of salt

Salt, similar to bed *A* above

Dolomite, gray and argillaceous, grading into two inches of anhydrite at base. Scattered crystals of salt

Salt, similar to bed *A* above

Anhydrite with argillaceous [illegible]

Salt, dark colored due to many small disseminated particles and a few small veins, of anhydrite and dolomite

Dolomite, gray and argillaceous grading into anhydrite below. Few veins of red fibrous salt

Salt, similar to bed *A* above

Anhydrite and salt
Salt, colorless to white
Anhydrite with some crystals of salt

Salt, dark colored due to many small, uniform disseminations of anhydrite and dolomite. Analyses of three selected samples show the strata to have the following range of composition.
Insoluble in water, 0.6 to 4.4 per cent
Insoluble in HCl, 0.1 to 0.6 per cent
Soluble only in HCl, 0.6 to 1.4 per cent
Sulphate mainly Ca, 1.8 to 2.8 per cent
Chloride mainly Na, 92.8 to 97.3 per cent

Dolomite, gray, finely crystalline and very argillaceous grading into anhydrite below. Scattered crystals of salt and small veins of red fibrous salt

Salt, similar to bed *C* above

Anhydrite and salt
Salt, colorless to white
Anhydrite and salt

Salt, similar to bed *C* above

Anhydrite and salt

Salt, similar to bed *C* above

Anhydrite and argillaceous dolomite
Salt, similar to bed *C* above
Anhydrite, salt and argillaceous dolomite

Salt, similar to bed *C* above

Anhydrite, with a few scattered crystals of salt

Salt, similar to bed *C* above, with several thin bands of anhydrite

Anhydrite and argillaceous dolomite, with scattered crystals of salt in upper part

Salt, similar to bed *C* above, with a few thin bands of anhydrite near top

Argillaceous dolomite and salt grading into argillaceous dolomite and anhydrite below
Salt, similar to bed *C* above. [illegible]
Argillaceous dolomite and anhydrite grading into anhydrite below

Salt, colorless to white
Anhydrite
Salt, colorless to white, with two thin bands of anhydrite near top

Anhydrite
Dolomite, light brownish gray and finely crystalline, with scattered dolomite crystals

Anhydrite, gray

Dolomite, gray to brownish gray and finely crystalline with partings of carbonaceous material and a few scattered crystals of salt in lower half

LINGUISTIC PROCESSES AS ILLUSTRATED BY WAR SLANG *

EUGENE S. McCARTNEY

THE phrase, 'to swear like a trooper,' used to be the sole recognition of the linguistic achievements of the soldier. Today the fourth age of man may still be 'full of strange oaths,' although it has discovered an additional outlet for its verbal originality. A contemporary Rip Van Winkle who slept through the duration of the World War would find bewildering the vast body of soldiers' slang that originated or became familiar during his protracted sleep.

Had the war lasted much longer, Esperantists might have found a partial fulfillment of their hopes of a uniform language in the *lingua franca* that was developing out of the babel of tongues at the front. The vocabulary of the British Tommy included a number of terms imported from India by England's professional army, a few German words used largely in mockery, and many distorted versions of the French. In addition many of his 'trenchisms' had a colonial color.

The soldier was as fond of his trench talk as a quick-lunch waiter is of his lingo, or a baseball player of his slang, or a yeggman of his cant. There were fads and fancies in military slang, and the due observance of the little niceties and proprieties found its counterpart only in things sartorial. Many expressions that were in vogue during the early part of the war, having been created to meet special needs, were hopelessly out of style at the end. Commanders in the rear failed at times to understand fully despatches from the front because they had not had opportunity to note the latest verbal fashions in the trenches. Some American officers even recommended that troops familiarize themselves in advance with current military slang.

* I have changed the title of this article since its presentation. The first four paragraphs are extracted in almost their original form from an article called *Trench Talk, The Texas Review,* 4: 73–87.

The idiom of the trenches manifested the same characteristics as does slang in civil life. It consisted of the humor of miscalling things; of transfers of names of familiar objects to new devices and contrivances; of the creation of onomatopoetic words; and of the adoption of foreign words intact or in distorted forms. The need for emergency words was so great that there was neither time nor inclination to despatch legates to unabridged Greek and Latin dictionaries in a frantic search for roots for new expressions. It is said that in soldiers' slang the most successful innovators were the airplane mechanics who had once been street gamins in Paris or costermongers in London.

The speech of the educated is apt to be artificial and unimaginative and woodenly correct. A soldier in a dugout regards linguistic conventions as little as did his troglodytic ancestors. His slang is not due to 'lawlessness of language' for the sake of lawlessness, nor to a desire to conceal thought, although it may result at times in the mystification of the uninitiate. It is to be ascribed to his desire for variety and color. It is one manifestation of his response to the stimulus of new surroundings.

Extensive collections of French, German and Austrian war slang have been printed in book form. Even the Swiss have a fairly corpulent pamphlet on the subject. Several articles and lists of British-American slang appeared during the war; my own compilation numbers some fifteen hundred words and expressions, many of which are war-time creations.

Amid the throes of the conflict great nations found time to collect material for prospective military museums. Future generations would doubtless prize as a linguistic museum a complete record of the language of the trenches.

The World War has given philologists an unparalleled opportunity to study a vocabulary in the making. New ways of living and thinking, strange situations and experiences, fresh associations and relations with all parts of the world, novel methods of fighting and many other circumstances combined in affecting the speech of belligerents and to some extent of civilians. In the eyes of the student of language the special appeal of the war-time vocabulary lies in the fact that no other equally

restricted period in the world's history provides so many illustrations of the operation of linguistic principles.

The dictionary has been called a 'thesaurus of faded metaphors.' The slang vocabulary of the soldier consists to no small degree of metaphors whose vividness and freshness have not yet faded. The reason a trench helmet was called a 'tin hat' is perfectly obvious. A certain type of howitzer was called 'grandmother' because it was short and stout. 'Coal box' was an apt name to apply to a heavy shell which on exploding made a cloud of dense black smoke.

These transfers of meaning are no more violent than those seen in 'ace,' an aviator with at least five victories to his credit, and in 'feather,' the ripple or wake left by the protruding periscope of a submarine, yet the latter words gained technical acceptance because they filled a need. When the French called bullets 'chestnuts' (*marrons*) and 'prunes' (*pruneaux*), the usage was obviously slang, yet the Roman legionaries named certain leaden missiles 'acorns' (*glandes*), and the transfer gained ready recognition because it met a real need. Doubtless the words cannon (from *canna*, a reed or pipe), torpedo (a fish) and grenade (pomegranate) were granted a begrudging admission to the fraternity of respectable words. The metaphors have, however, faded so completely that only the etymologist is aware that they once existed.

If there is a genuine need for a word, it is almost impossible to proscribe it. In the American navy the term 'oil-slick' was applied to the tell-tale streak of oil from the exhausts of submarines running close to the surface. "The British Admiralty did not approve of the term at first, but nobody in the Admiralty could present a better descriptive phrase, so now it is officially recognized, but with due British reservation." [1]

The change from one part of speech to another is frequently illustrated in soldier talk. 'Crump,' an onomatopoetic coinage for a heavy shell, was employed also as a verb, e.g.: "The Germans 'crumped' the village daily." The transformation of an adjective into a noun may be seen in 'Old Contemptibles.'

[1] *The Saturday Evening Post*, Oct. 12, 1918, p. 90.

It will be recalled that at the outbreak of war the Kaiser spoke scornfully of 'England's contemptible little army.' 'To have one's wind up' meant 'to be afraid,' but finally 'wind-up' became a compound noun. In 1914 General Gallieni promised the Parisians to defend them *jusqu'au bout*, 'to the limit.' The phrase made a strong appeal and those who were determined to fight to the last called themselves *jusqu'au boutistes*, 'bitter-enders.' Even a sentence could be used as a noun. Allied raiding parties carried with them strands of barbed wire made into a noose to be used on stubborn prisoners. These devices were dubbed 'come-along's.'

Extension of meaning may be readily illustrated in war slang. The idea of worthlessness in 'dud' was the basis for the transfer of this word to apply to an unexploded shell; finally this use caused anything worthless, even a person, to be called a 'dud.' 'To go west' meant 'to die,' but eventually a soldier might speak of an airplane as having 'gone west.' The word 'camouflage,' which is evidently connected with pre-war thieves' cant, *se camoufler*, 'to disguise one's self,' spread like influenza among soldiers and civilians alike. Toward the end of the war it seemed that it might become an accepted word in its non-technical sense, but it was overworked to such an extent that people dropped it after a short vogue.

The campaign for food conservation, which was aided and abetted by placards urging housewives to 'Serve just enough,' and then to 'Save what's left,' caused a great extension of the suffix *-less*. 'Meatless,' 'wheatless,' 'porkless,' and the like, are forms undreamed of in days of peace-time plenty. At one time it seemed that the word 'Hooverize' might struggle for recognition, but its popularity died as its novelty waned.

One might suppose that soldiers among themselves would have no need for euphemisms, yet they balked at the word lice. This troublesome pest masqueraded under many polite and playful pseudonyms, such as 'cats,' 'cooties,' 'coddlers,' 'pants-rabbits,' 'seam squirrels.' The French called them *graine de torticolis*, 'necktwisting seed'; the Italians, *cavalleria*, 'cavalry'; the Germans, *Biene*, 'bee,' *die russische Biene*, 'the Russian

bee.' *Kostgänger*, 'boarder,' *der russiche Kriegsfreiwillige*, 'the Russian war-volunteer.' A pun at the expense of the unfortunate Russian emperor is seen in *Nikoläuse*.

The words 'sausage,' an observation balloon, and 'ace' are translations of the French words *as* and *saucisse*. 'Arrivals,' from *arrivées*, and 'departures,' from *départs*, are likewise instances of borrowing. When a Tommy spoke of machine-guns as 'pouring out concentrated hate,' he used the word in a concrete sense which goes back through intermediate stages to the German 'Hymn of Hate.' 'Punish' in the sense of shell was due to the German use of *strafen*.

A few illustrations may be given of the way words were treated (or mistreated) while undergoing vernacularization. Vernacularized versions of French are seen in *napoo*, 'nothing more' (from *Il n'y a plus*, or, *n'a p'us*), *tootfinny*, 'all done' (from *tout fini*), and in *toots sweet*, 'hurry up' (from *tout de suite*).

To contact with the people and soldiers of India before and during the war is said to be due the introduction of the words 'Blighty' (literally 'foreign land,' then 'England'), 'char' (tea), 'dekko' (a look, or, to look), 'doggo' (still, quiet), 'jildi' (hurry), 'rooti' or 'rooty' (bread).

Clipped forms similar to auto and 'phone occur in 'torp' (torpedo), 'sub' (submarine) and 'hippo' (i.e., 'hippopotamus,' a type of airplane).

The effect of war-time prejudice is seen in the quick-lunch waiter's substitution of 'liberty cabbage' for sauerkraut and 'liberty steak' for Hamburg steak.

The impression was prevalent in some quarters during the war that the soldiers originated many of the words they used so glibly. This view obtained with regard to French slang especially. Reference to French slang dictionaries will show, however, that many words made familiar by the conflict existed long ago, some of them in the cant of thieves and in the *demi-monde*. In English words like 'kip' (sleep, bed) and 'doss' (sleep, perhaps from *dorsum*, 'back') seem to be fresh creations, yet they are found in a thief's autobiography of over a generation ago.

Ancestorless words like 'gas' are extremely rare. Words do

not, Athena-like, spring forth full-grown from the head of a linguistic Zeus. There are, however, a few words without pedigree in the slang of the soldiers, chiefly those of an onomatopoetic character. 'Crumps' were so named because they made a sort of cr-r-r-rump when they exploded. Other names of somewhat similar origin are 'pip-squeaks,' 'pom-poms,' 'whees,' and 'whizz-bangs.' The *poilus* called a motor-cycle a *teuf-teuf* and the Germans designated the anti-aircraft gun *Wau-Wau*.

There is still another type of original word-creation, the uniting of the initial letters of several words. This occurs in 'Anzac' which is derived from *A*ustralian-*N*ew *Z*ealand *A*rmy *C*orps.[2] In England a member of the *W*omen's *A*rmy *A*uxiliary *C*orps was called a Waac' (written 'fonetically' at times as 'Waak'). By a partial application of the same principle, perhaps under the influence of 'Waacs,' 'Wrens' came to designate the Women's Royal Naval Service.

Popular etymology too has played a part in the war vocabulary. A section of the Hindenburg Line was named after Hunding, the rascal of the Nibelung. Illiterate German soldiers are said to have confused the name with *Hundling*, 'little dog.' The German Minenwerfer, 'trench mortar,' has undergone an amusing transformation into *mine à faire peur*, 'fear-making mine' and *mine de chemin de fer*, 'railroad mine.'

A popular explanation of the name 'Sammy' was broadcasted during the war. It is said that American soldiers arriving in France and hearing the cries *Vive les amis* thought that they were being addressed as Sammy. The name, the etymology of which seems obvious, was an attempt to find a cousin for Tommy Atkins. Incidentally the name Sammy illustrates the folly of artificial stimulation of words. The soldiers detested the nickname and *Stars and Stripes* was unsparing in editorial disapproval. It required the efforts of several newspaper pulmotors to keep the word from dying an early death.

Soldier slang makes vivid the manner in which objects acquire their names. No word can picture fully the size, shape,

[2] It is said to have originated as a code word in despatches to the *Sydney Morning Herald*. I am told that there are other explanations for this word.

color and other characteristics of a thing. As a rule one prominent aspect is singled out in the naming process and the rest are disregarded. Various peoples have picked out different traits of the squirrel and named it 'leaf-dweller,' 'shadow-tail,' 'tail-in-air,' 'chatterer,' 'little leaper,' 'little oak-kitten,' 'tree-fox,' 'acorn mouse,' and the like. We may see the same principle of selection in the naming of the machine-gun. Its mechanism, its shape, the noise it made, reminded the soldier of so many things in daily life that he bestowed upon it a multiplicity of sobriquets. The English called it 'typewriter' and 'riveter'; the French, *faucheuse* ('reaper'), *machine à coudre* ('sewing machine'), *moulin à café* ('coffee-mill'), *moulin de rata* ('hash-mill'), *turlutine* ('titlark'), *machine à signer les permissions* ('furlough-signing machine'); the Italians, *capra*, ('goat'), *cavaletta* ('locust'); the Germans, *Drehorgel* ('barrel-organ'), *Fleischhackmaschine* ('mincing-machine'), *Giesskanne* ('watering-can'), *Kaffeemühle* ('coffee-mill'), *Mähmaschine* ('mowing-machine'), *Steinklopfer* ('stone-breaker'), *Stottertante* ('stuttering-aunt'), *Totenorgel* ('death-organ'), *Weibergosche* ('gossiping hag').

The shape and general appearance of certain fruits and vegetables have given rise to the following transfers: 'lemons,' meaning grenades; 'pineapples,' grenades; 'toffy apples,' bombs; 'gooseberries,' wire entanglements; 'onions,' flaming shells or rockets. Illustrations from the French are *citron* ('citron'), bomb; *pommes de terre* ('potatoes'), observation balloons; *marrons* ('chestnuts'), bullets; pruneaux ('prunes'), bullets.

If there had been no generic words for bomb and grenade at the beginning of the war, various words that originated in fancy or from some superficial characteristic could have supplied candidates for the honor, for example, 'jam-tin,' 'cricket ball,' 'hairbrush,' 'pineapple,' 'potato-masher,' *queue de rat* ('rat-tail'), *tuyau de poêle* ('stove-pipe'), *tête à Guillaume* ('William-head').

Animals have been frequently honored in the military vocabulary because some more or less fanciful resemblance to their size, shape, traits, or habits has been seen in various weapons and contrivances. A few instances may be cited: 'camel,'

'dolphin,' 'hippo,' 'penguin,' 'pup,' all of which are types of airplanes; 'caterpillar,' a tractor; 'elephant,' an observation balloon; 'flying-pig,' a trench-mortar projectile; 'whippet,' a mobile English tank; in French, *chat* ('cat'), the 75-millimeter gun; *crapouillot* ('toad'), a squatty trench-mortar; *turlutine* ('titlark'), a machine gun; in Italian, *capra* ('goat'), a machine gun; *locusta* ('locust'), a machine gun; in German, *Kettenhund* ('watchdog') and *Windhund* ('greyhound'), French 75-millimeter shells; *Stinkwiesel* ('skunk'), a French high explosive shell; *Blindschleiche* ('slowworm'), a low-velocity shell; *schwarze Biester* ('black beasts') and *schwarze Säue* ('black sows'), heavy shells common to the Allies. 'Kiwi,' sometimes written 'kewee,' was the designation of an aviation officer who never left the ground. The word is properly the name of a New Zealand bird, the apteryx, which has only rudimentary wings.

Historical personages are duly honored or dishonored by soldier humor. Among the French *Louis-Philippe* was a trench-mortar. A member of the military class of 1916, which was summoned in advance of its time, was a *Marie-Louise*, so called in allusion to the fact that at the time of the marriage of Napoleon to Marie-Louise, France was calling up boys. *Tête-à-Guillaume*, 'grenade,' is obviously a reference to the ex-Kaiser. At the beginning of the war the Italians dubbed the Austrian sharp-shooter *Cecchino*, the familiar form of the name Francesco, i.e., Francesco Giuseppe (Francis Joseph). After the death of the aged Emperor the name *Carlino* ('little Charles'), or the pejorative *Carluccio*, was substituted. 'Big Bertha' and 'Long Bertha' are guns named from Bertha Krupp. A 'Jack Johnson' was a big German shell so christened when the colored prize-fighter was still champion.

Baptismal names are common, for example, 'Archibald' or 'Archie,' an anti-aircraft gun; 'Rupert,' a kite-balloon; in French, *Rosalie* and *Joséphine*, 'bayonet'; *Charlotte* and *Eugène*, the 75-millimeter gun. The English soldier was called 'Tommy'; the Australian, 'Bill-Jim'; the Scotch, 'Jock.' Wide-spread propaganda was partially successful in inflicting 'Sammy' on the doughboy. To the German the Russian is 'Ivan.' The

German was known to his Anglo-Saxon opponents as 'Fritz,' 'Hans,' 'Heinie,' and 'Jerry,' while the Turk was 'Abdul Pasha.'

The gastronomic slang of the soldier is in large measure of the same character as that of the civilian. In the American army dumplings were 'sinkers'; milk was 'cow'; pastry as doled out by the Salvation Army, 'ammunition'; beans, with slices of ham, 'stars and stripes'; corn whiskey, 'gray mule' or 'white mule.' Among the British 'bully beef' was a kind of corned beef; early morning tea was called 'gun-fire,' evidently an allusion to the early morning cannonade characteristic of one period of the war. The French had their *singe*, 'monkey meat.' Coffee was *jus*, 'juice,' and a bad soup was *lavasse*, 'dishwater.' The words granite and shrapnel figured largely in the German dietetic vocabulary. A potato was a *feld-grau*. A familiar type of humor was manifested in the Italian *suola*, 'sole of a shoe,' to describe hard and tough meat. *Riso e verdura*, a soup made of rice and vegetables, became in the lingo of the soldier, *riso e pezze da piedi*, 'rice and foot-cloths,' because of the presence of big leaves which resembled the long broad pieces of linen that were wrapped around the feet as a substitute for stockings.

Slang, which is often deliberately humorous, incidentally gives rise occasionally to an amusing situation. At the beginning of the war an English girl told her sweetheart that if he did not enlist she would 'cut him dead.' A German newspaper wishing to illustrate how rampant the war-spirit was in England told how an English girl said that if her sweetheart did not enlist she would 'hack him to death.'

In Australian slang 'dinkum' means 'on the square,' 'on the level.' At Gallipoli a man dressed in a British uniform was giving orders to some Australians. Becoming suspicious one of them asked: "Are you fair dinkum, Major?" The reply came: "Yes, I am Major Fair Dinkum." The 'Major' died soon after of "lead in the head."

The use of slang gave rise to at least one international misunderstanding. In British slang a nervous breakdown was called 'barbed-wire disease.' I now quote part of a clipping from the *New York Times* for May 27, 1918: "Turkish officials

that have heard the expression translate it literally. Wherefore the Turkish government, in ratifying the agreement with the British for an exchange of prisoners, stipulated that plain wire should be substituted for barbed-wire around prison camps for Turks in English territory."

Like ordinary dictionaries slang dictionaries have words and expressions whose pedigree it is hard to establish. It seems to me, however, that there can be but one explanation of the expression 'to go west.' The land of the setting sun is always regarded as the land of the dead. In pagan mythologies the dead have been going west for centuries. When Ulysses went to the regions of the departed he directed his course westward.

A very plausible explanation of the word 'doughboy' is recorded in Thornton, *An American Glossary*.[3] "A doughboy is a small round doughnut served to sailors on shipboard, generally with hash. Early in the Civil War, the term was applied to the large globular brass buttons of the infantry uniform, from which it passed by natural transition to the infantrymen themselves."

A correspondent of *The New York Times* of Oct. 13, 1918,[4] writes, however: "I have known of the term 'doughboy' as applied to infantry soldiers for 70 years; it did not originate in the Civil War, but was in use long before it in the British Army." Reference to the Oxford dictionary will show that the word was applied to 'cakes of bread' as early as 1685.

The fruitful time for derivations is when the history of a word is lost or shrouded in mist. The following explanations of 'doughboy,' culled from various sources, illustrate what may be called the 'mythology of slang.'

"I believe that the name comes from a Spanish word, and was given by the American cavalry to the infantry during the old war in Mexico, because the infantry were usually covered with dust."

"Another story has it that during some maneuvers in Texas an artilleryman, comfortably perched on a gun, saw a soldier

[3] Quoting Mrs. Custer, *Tenting on the Plains*, p. 516 (1888).
[4] Editorial section, p. 2.

hiking by in the thick, sticky Texas mud. The mud was up to the shoetops of the infantryman and the upper part which had dried looked almost white. 'Say,' shouted the artilleryman, 'what are you doing? Walking in dough?' And so the men who march have been doughboys ever since."

Still another explanation would make the word an importation from the antipodes, connecting it with an aboriginal Australian murderer named Doughboy.

Illustrations of military slang might be quoted *ad infinitum*, but sufficient instances have already been given to show the process of vocabulary-building. However much one deprecates the use of slang in civil life, he can condone it in the case of the soldier. It affords an index of the soldier's nimble wit, his alertness of mind and receptivity to new impressions. In addition on many occasions verbal humor has acted as a safety-valve to pent-up emotions.

The odd and grotesque and whimsical in the war vocabulary have been short-lived, or at least have been relegated to the barracks since martial topics have ceased to monopolize the conversation of every gathering. Though a post-bellum edition of a large dictionary stressed the inclusion of the verbal creations of the war within its covers, it can not be said that many words have been elevated permanently to the linguistic peerage. The technical military vocabulary has, however, been distinctly enriched.

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METEOROLOGICAL DATA, DOUGLAS LAKE, MICHIGAN, 1922

FRANK C. GATES *

THE data here reported were obtained during the summer of 1922 at the University of Michigan Biological Station on Douglas Lake, Cheboygan County, Michigan.

June, 1922. — A rather cold month — the coldest of the three years of which there is at least twenty-four days record. The average 60.9° was 4.4° below that average. On the 26th a freeze occurred with a temperature of 30° at the station and as low as 28° in the region nearby. This is the first occurrence of freezing temperature during the session time. The effect was pronounced in the low spots. The rainfall was 0.80 inches above the three-year average.

July, 1922. — Likewise a cold month, being exceeded in that respect only by July, 1920, when the average was 1.6° lower. Although the average daily maximum at the station for July is 80°, that temperature was reached but six times during this month. It was by far the rainiest July the station has ever experienced. The previous maximum of 3.07 inches was exceeded by 2.98 inches. Had a severe thunder storm which passed two miles north of the station on the 30th gone over the station, this July would have been the rainiest month in the station history.

August, 1922. — This month was very pleasant. It scarcely varied from the average in temperature, but was a little over one half of an inch deficient in rainfall.

Considering the eight weeks of station session, the rainfall (8.37 inches) was the heaviest of the eleven years of record,

* Contribution from the Department of Botany, Kansas State Agricultural College; No. 201.

being 0.52 inches above that of 1912, previously the rainiest, although in 1922 it took place on sixteen days, whereas there were twenty days of rainfall in 1912, 1915, 1920 and 1921.

In the table following the temperatures are expressed in degrees Fahrenheit, the rainfall in inches; the departures are from the averages of the eleven years of record, 1912–1922.

METEOROLOGICAL SUMMARY FOR SUMMER OF 1922

Month............ Days of record....	June, 1922 24	July, 1922 31	Departure	August, 1922 21	Departure
Absolute maximum	87	87	−17	91	−8
Average maximum	71.8	74.4	−5.6	76.6	−0.1
Absolute minimum	30	42	+3.5	45	+5
Average minimum	50.5	54.1	−3.0	55.9	−0.2
Mean temperature	60.9	64.3	−4.3	66.1	−0.2
Precipitation......	2.92+	6.05	+3.88	2.27+	−0.58
Days of precipitation	6	12	+3	4	−3

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THE DETECTION OF DIABETES

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We shall concern ourselves with one small angle of the complex metabolic disturbance known as diabetes. This is a disease which holds profound scientific interest, yet aside from the scientific aspect, every educated individual should be vitally concerned and somewhat disturbed over the diabetic situation viewed in the light of an important public health problem. It is estimated that as a nation we have about a million diabetics in our midst; in Detroit there are roughly ten thousand diabetics. But how many of these thousands of people have been diagnosed as diabetic? How many know that they have the disease? Probably a comparatively small number — likely not over a thousand.

Statistically the incidence of diabetes is increasing rapidly and if it continues to increase in the next thirty years as it has in the last thirty years it will equal tuberculosis as a cause of death. Again, according to statistics, if it continued to increase in the next two generations as it has in the last generation, it would be responsible for almost the entire mortality of the world. Of course the statistics are incorrect and the apparent increase of the disease is due to an increase in the percentage of correct diagnoses. This apparent increase of the disease will continue for a long time or until routine urine examinations are made for each individual once or twice yearly. Statistical increase in the incidence of diabetes simply means greater accuracy in diagnosis.

In New York City the death rate in the last thirty-five years has been reduced 50 per cent but diabetes has increased 600 per cent as a cause of death. Joslin makes the statement that the frequency of diabetes in a community is an index of the intelli-

gence of its physicians. The apparent increase of this disease is due, in addition to the improvement of statistics and more careful examinations, to the general increase in the duration of life. It has been shown that the average age at death has been practically doubled in the last half a century and, as in cancer, the longer a person lives the more liable he is to have diabetes.

It appears that diagnostic methods are improving as is also the treatment. But the successful treatment of the disease depends upon its early detection. It is the apprehension of the disease in its mild form which will make it possible to maintain an individual in a state of health and strength and, provided he is somewhat intelligent, to enable him to attain the age which he otherwise would without inconvenience to himself other than that imposed by a careful diet, a reasonable mode of living, or by one or more short courses of insulin treatment.

Diabetes in the past has been considered synonymous with glycosuria, and later that idea was modified so that diabetes was defined as a disease in which there was a diminished tolerance for carbohydrate on the part of the body, or, in other words, there was an impaired ability to assimilate and utilize glucose; and the statement is usually added that as a consequence glucose is eliminated in the urine. As we now understand the disease the immediate cause is diminution in the amount of the secretion of the islet tissue in the pancreas and the etiology of this condition is unknown except that infection, excessive diet, strenuous living, nervous strain, and the like, are mentioned as possible causes.

The first part of the definition just given is not very satisfactory but undoubtedly quite correct and acceptable. Of course there are the typical symptoms such as polyuria, polydipsea, loss of weight, the frequent complications such as the easily acquired infections and gangrene, and the acidosis and coma of the severe types. But the second part of the definition is not always true. Not all diabetics have sugar in the urine, in fact about 20 per cent do not. On the other hand, about 15 per cent of individuals having positive urinary sugars do not have diabetes. So there is an error of approximately 35 per cent

in urinalyses in connection with diabetes and our former criterion of the disease, i.e., glycosuria, must be modified and applied with care. So we may merely say glycosuria is a symptom of the disease and indeed the most important and trustworthy symptom of all.

Of course when we speak of positive and negative sugar findings in urine we do not mean what we say at all. Our understanding of glycosuria has been changed. We know now that all normal urine contains sugar in amounts usually about .1 per cent and sometimes as much as .2 per cent. These are amounts which are not detected by the ordinary qualitative reagents which lack delicacy of reaction. We also know that if enough carbohydrate is fed sugar will be excreted in the urine in most cases. So a sharp line of demarkation cannot be drawn between normal and pathological urines with reference to sugar content.

We also speak of a urinary threshold for the blood which is the lowest concentration of the blood sugar which will cause an appearance of sugar in the urine. We have, in the past, visualized the sugar threshold as being comparable to what takes place in the case of a dam in a river. The water before the dam represents the sugar in the blood and the kidney the dam. When the blood sugar was normal, or from 80 to 125 mg. per cent, the level did not reach the top of the dam, but as the concentration was increased to about 160–180 mg. per cent, the sugar overflowed into the urine. Now we are forced to imagine small holes or a spillway in the dam to illustrate the passage of a small amount of sugar normally through the kidneys. In diabetics the dam is higher than in normal individuals and that is the reason why many rather advanced diabetics are sugar-free. If their diet is light, and they drink much water, their threshold having been increased, their blood sugar may range from 150 to 200 or even more and the urine be negative. Also the treatment of diabetics with a sugar-free urine as the goal lacks accuracy; the usual control to treatment does not give the information desired.

Certain people may be isolated and formed into a group, members of which, experience has shown, are especially predis-

posed to diabetes. Four classes can be made in this group of people and we know that, to a varying degree, these classes present a tendency to diabetes:

1. Those with a positive urinary sugar. This is, of course, strong evidence, but further proof should be secured.

2. Where heredity is a factor. I think it would be better to say where there is a familial tendency to diabetes, because that includes all direct relatives as well as parents and grandparents.

3. The incidence of diabetes is high among the Jewish race and especially the Russian Jews. Here there seems to be a strong hereditary influence.

4. The obese. Obesity and dietary excess precede diabetes in a large number of cases.

Any individual falling into any of these groups should receive a careful laboratory examination. A urinalysis is, of course, the first thing. Next is a blood sugar estimation and this should be made at fasting level. For this we routinely take the specimen of blood in the morning before food, delaying breakfast to suit our convenience. If the blood sugar taken under these standard conditions is above normal, the diagnosis is established. But suppose, for example, that the urine showed a weakly positive or a trace of sugar, or the presence of sugar intermittently, and the blood sugar was between 120 and 135 mg. per cent. Such a finding is quite frequent. The physician knows about as much with this information before him as he did in the beginning. It would be wrong to pronounce the patient free from disease and certainly no definite findings are at hand to confirm a diagnosis of diabetes. This patient probably has not a characteristic symptom.

It is just such a situation that makes the diagnosis of all diseases difficult. If any disease presents a frank and open case, its symptoms are distinct, the condition checks up well with the requirements laid down by the text book, and little trouble is encountered in arriving at a correct diagnosis. But it is the mild attack which most frequently presents the real difficulties because of the indefinite appearances and atypical findings.

Fortunately in diabetes more delicate methods of diagnosis may be easily employed. We can accurately measure the ability of the individual to utilize sugar, now that accurate microchemical methods of blood analysis are available. Of course this is a physiological test and quantitatively it has its limitations, but surprisingly accurate information can be obtained.

The technique of the test is as follows: A sample of blood is taken before food in the morning. One gram of glucose is then given by mouth per pound of body weight. The glucose is dissolved in about 300 mils of water, flavored with lemon juice, and served cold. At the end of half an hour, one, two, three and four hours, specimens of blood are taken, and the percentage of glucose estimated. The patient voids before the test and the percentage of glucose in this specimen is determined. Specimens of urine are secured along with each sample of blood, and the amount of glucose eliminated during the test is estimated as well as the volume of water taken and the amount of urine voided, and these figures compared with the normals.

The blood finding alone will be considered here. The fundamental principle involved is that in a normal subject, after the intake of this amount of glucose, the blood sugar will return to normal within three hours.

Case No. 8993. Female. Age 22. Family history of diabetes. Typical normal sugar curve (See Fig. 7).

Case No. 9920. Female. Age 40. Family history of diabetes. Sugar in the blood returned to normal at the end of four hours. This case could be classed as a "prediabetic" or a very mild diabetic. This is the most important discovery of all because, when a diagnosis is made, this early slight modification of diet will usually prevent an increased intensity of the condition. And sometimes, after modification of diet for a period, a normal tolerance will return. I used the words "prediabetics" and "mild diabetics" and probably subject myself to criticism for so doing, but I think these words are very descriptive.

Case No. 8134. Male. Age 54. Trace of sugar upon one occasion, but urine was usually sugar-free. Curve shows a

moderately severe diabetic. This patient probably had sugar in the urine at intervals, but one may not discover it at the time of examination. This man would probably be extended life insurance by almost any company even though he would make a bad risk.

Case No. 7317. Female. Age 48. Glycosuria for years. Usually one half per cent to one per cent of sugar in the urine. Scared to death of diabetes and subjected self to a rigid diet for

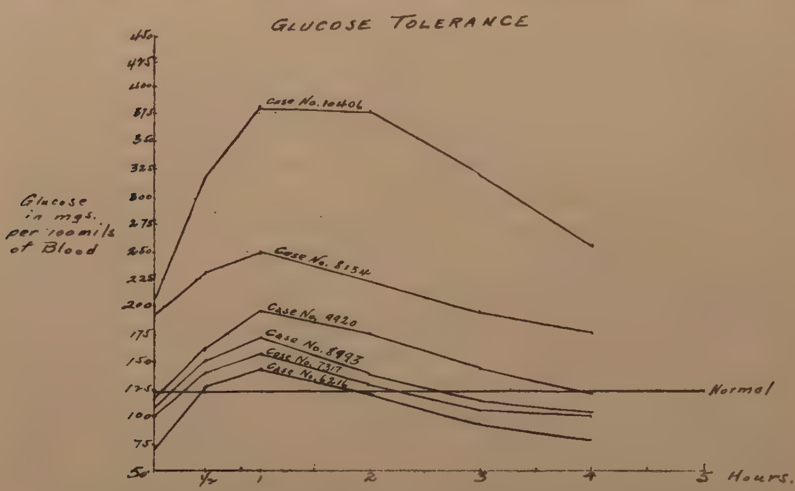

FIG. 7. Graph showing Glucose Tolerance in Diabetes Patients

a long time. This is a case where glycosuria does not mean diabetes because the curve shows an unusual ability to assimilate glucose. Such a person would be rejected by a life insurance company. This case shows that one cannot afford to stop at a uranalysis.

Case No. 6216. Female. Age 22. Had considered herself diabetic for years. Was formerly overweight but following the institution of a rigid diet her weight fell to 78 pounds. Urine always contained between 5 per cent and 9 per cent glucose. General health good before diet restriction, but now complained of weakness. Test shows an increased permeability of the

kidney to sugar and a very good carbohydrate tolerance. After the patient was told of her true condition and restriction on diet removed, her worrying ceased, she returned to normal weight, and did not complain further of ill health.

Case No. 10406. Male. Age 28. A severe diabetic with marked glycosuria.

CONCLUSIONS

1. If sugar is found in the urine, a fasting level blood sugar should be run to determine whether glycosuria is due to hyperglycemia or to an increased permeability of the renal filter.

2. Glycosuria is not a definite indication of diabetes, but hyperglycemia is. In mild cases, however, hyperglycemia may not be sufficiently marked to furnish conclusive information.

3. If the result of the blood sugar determination still leaves doubt, the carbohydrate tolerance of the individual should be obtained.

4. Glucose tolerance tests should be made upon the "diabetic types" in order to detect the disease in the developmental stage and thus provide for effective treatment.

5. It would seem that diabetes must soon become a public health problem, and that an educational campaign should be instituted which would be national in extent in order to impress upon everyone the importance of diet and exercise, and to inform the practitioner of the means of diagnosis and the control of diet.

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THE VIABILITY OF *LEPTOSPIRA ICTEROIDES* IN CULTURE

PHILIP HADLEY

Leptospira icteroides, now recognized as the causative agent of yellow fever, was first cultivated in an artificial culture medium by Noguchi in 1918. The medium was made up of serum and salt solution plus either gelatin or agar, or sometimes citrated plasma. In such media the spirochaetes grew abundantly for a number of weeks or months. Using as a basis the essential elements of the Noguchi medium, the present writer has attempted certain variations which might enable the spirochaetes to live in culture for a longer time.

The medium which has given the best results is prepared and inoculated as follows: A rabbit is bled from the heart for 15 to 20 cc. of blood, from which the clear serum is separated. Of this 1.5 cc. is placed with a sterile pipette into a sterile 15 cc. centrifuge tube. To this is added 3.5 cc. of sterile physiological salt solution or of sterile distilled water. The tube is then placed in a water bath at 56° C. and the serum-salt mixture partially inactivated by heating for ten minutes. The tube is then allowed to cool to about 40° C. To the serum-salt mixture is then added 1 cc. of melted agar at a temperature of about 56° C.

The agar is prepared as follows: Shred-agar is washed several times in distilled water, then dried to a constant weight in the oven. Of this 2 grams are added to 100 cc. distilled water and boiled until dissolved, when it is cooled to about 60° C. About 10 cc. of distilled water containing a little dried egg-albumen is then added, stirred in, and the agar again heated to 134°–140° C. for ten minutes. While hot it is filtered through paper and placed in a number of culture tubes each holding

about 10 cc. It is then sterilized in the autoclave at fifteen pounds pressure for fifteen minutes. When required for use it is melted by boiling and cooled to about 56° C. before adding to the serum-salt mixture.

After the agar has been added, it is thoroughly mixed and the tube placed in a 40° C. water bath where it is held until shortly before inoculation, which is accomplished as follows:

A guinea pig which has been inoculated three to four days previously with a liver-mash suspension in sterile tap water of *Leptospira* is killed by a blow at the back of the neck, and opened, with sterile instruments, under strictly aseptic precautions. If the instruments have been boiled in soda solution or borax, the fresh set instruments employed to open the peritoneal cavity are first rinsed in sterile distilled water. After the body wall has been cut through and the sides reflected, a lobe of the liver is removed with fresh sterile scissors and forceps and transferred to a sterile piece of filter paper lying on the bottom of a sterile Petri dish, where it remains until a tube is prepared for removing a sample of liver tissue.

A plugged culture tube previously sterilized in the oven at 200° C. for several minutes is drawn out in the blast flame to give a small segment of thin glass tube about 5 mm. in diameter. When cool the attenuated portion is notched with a file and broken at a point where the side walls are parallel. The broken end is flamed quickly, the cotton plug pushed farther into the large end of the tube, and the tube stood on end to cool. The Petri dish is then opened, and, while the liver lobe is steadied with a pair of sterile forceps, the cutting tube is forced through the liver tissue at the point of maximum thickness in order to cut out a liver cylinder about 4 to 5 mm. in diameter and 12 to 14 mm. in length. The culture tube is now removed from the water bath and cooled to about 25° C. The plug is then removed and the loaded end of the cutting tube introduced close to the level of the medium. The cylinder of liver tissue is then gently blown out by putting the mouth over the plugged end of the cutting tube. It quickly falls through the medium to the bottom of the centrifuge tube, leaving behind it through the

medium a cloudy trail of blood. If sufficient blood to redden the medium has been introduced with the liver cylinder, the tube should now be centrifuged at two to three thousand revolutions per minute for a sufficient time to throw down the blood cells. With a sterile pipette sufficient pure sterile paraffin oil is now flowed upon the surface of the medium to give a depth of one centimeter. The tube is then capped with tin-foil and allowed to develop in a darkened place.

If kept at 37° C. the growth of spirochaetes comes on more quickly — five to six days, — but the organisms do not remain so long alive. The best results are obtained by growing at room temperature, or about 24° C. The stage of development of the spirochaetes may be observed in samples of two or three drops removed by means of a capillary pipette (made of drawn-out 6 mm. glass tubing), examined with the dark field illumination. The first samples should be taken from a point about one centimeter below the surface of the oil.

Ordinarily the organisms can be detected in small numbers (two or three per hundred fields of the microscope) within six or seven days after inoculation. They increase in number during the next week or two, usually reaching a maximum frequency of 300 to 600 per field after two or three weeks. From this time on the numbers decrease, so that, when the culture is old, it may be difficult to discover an organism even in several hundred fields. When present in maximum numbers the organisms present the picture of a squirming, writhing mass in which the individual specimens can be seen clearly only at the edges. In less crowded fields the individual morphology and the forms of movement can clearly be studied. As a rule the leptospiras from culture are longer than those from blood or tissues. Chains of organisms attaining a length of 160 to 180 micra are frequently observed.

Division forms are common and always result from fission in the transverse plane. *Leptospira icteroides* never divides by transverse fission, although forms are commonly seen which appear to give evidence of such a form of multiplication. A mature spirochaete becomes attenuated in or near the middle of

its long axis and the daughter cells separate. If the separation does not occur quickly, one of the daughter cells may come to lie parallel with the other and the two may become entwined while still joined at the tips. One of the forms of motion of the leptospira is a rapid rotation on its long axis. When the attenuation preceding division has occurred, both ends of the organism rotate, usually in opposite directions, and it is this twist which usually serves to cause the separation of the daughter spirochaetes. The most common type of division is that involving the separation of a single elongated organism into two daughter cells. Frequently in cultures, however, a filament 40 to 60 micra in length may segment simultaneously into three or four daughter cells the length of which may be variable. There is some evidence that the granules present at the proximal end of the motile segments divide preceding the division of the cell as a whole.

Ordinarily the culture medium in which the leptospiras are growing remains as clear as before inoculation. When the growth is nearing the maximum, however, there appears a zone of haziness about one centimeter below the surface of the oil. Here the spirochaetes are present in greatest numbers. In this zone are sometimes observed minute white flecks. When these are removed by means of a fine, sterile capillary pipette, and examined by the dark field illumination, they are found to comprise dense masses of active spirochaetes. When the spirochaetes die they undergo a granular degeneration, surviving for a considerable time as peculiar, shadowy, granular V-shaped bodies which increase in number as the culture ages.

During the time that the culture is living there are no evidences of chemical reaction produced by the organisms. After nearly two years the liver cylinder remains intact without any appearance of autolysis; there is no detectable change in reaction except when contaminations intervene. Ordinarily the growth of the leptospiras ceases, and the organisms die, at the first sign of contamination. There may be, however, contaminations with certain species of molds which are tolerated by the spirochaetes for a considerable time; but eventually they die,

for they are highly sensitive to even minute modifications in the medium.

Under the conditions of artificial cultivation outlined above, cultures may easily be kept alive for a year or more. One culture which was set up July 4, 1921, is still vigorous at the time of writing, a period of nearly one year and ten months. In this culture the spirochaetes are present at the rate of about one per field, and are highly active. The culture gives indication of being in the same active condition at the end of the two-year period. The cultures do not perceptibly lose their virulence as a result of artificial cultivation. One culture showed virulence at the end of about one year and nine months. With cultures of this age, however, several passages through guinea pigs are required to establish the virulence on its original scale. If sufficient volume of medium is used, it would appear that *Leptospira icteroides* in culture might be kept alive and virulent for many years.

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TRANSMISSIBLE LYSIS OF BACILLUS PYOCYANEUS

PHILIP HADLEY

A SAMPLE of pus from a suppurating lesion on the forehead of a patient was cultured for pyocyaneus. The culture obtained on slant agar presented unusual features. The surface growth was deeply pitted and corroded in certain parts. The pockets, which were for the most part round, varied in diameter from 1 to 5 mm. and extended down to the agar substratum. In these pocketed areas the culture had disappeared. When examined by transmitted light they were transparent, but when examined by reflected light they gave a marked iridescent effect, the color of bronze.

This pocketed culture was plated and yielded two sorts of colonies: one showed pocketed areas which frequently expanded to destroy the entire colony; the other was homogeneous and showed no pockets. The first type showed a delicate spreading growth and produced considerable blue-green pigment; the latter showed a more circumscribed and massive growth and produced no blue-green pigment. When the pocketed or "lytic" colony was sub-plated, it yielded both sorts of colonies, but when the homogeneous colony was sub-plated it yielded only homogeneous, non-pigmented colonies. When both sorts of colonies were subcultured on agar slants, the characteristic features were maintained for many generations.

Since this phenomenon resembled the case described by Twort [1] for the lysis of staphylococci obtained from glycerinated vaccine virus, and also certain aspects of the D'Herelle phenomenon, a further study was made of the pyocyaneus from the

[1] *British Lancet*, 1915, p. 1241

viewpoint of a transmissible lytic agent. The main results of the study are as follows:

1. Filtrates from the lytic cultures possess a lytic action for sensitive cultures of pyocyaneus, but not for the original culture.

2. Filtrates from the non-lytic cultures possess similar lytic power, but not for the homologous strain.

3. When the lytic filtrate is mixed with a sensitive culture and then streaked on agar slants, there appear in the growth lytic areas comparable with those described by D'Herelle for his Bacteriophage. The number of lytic areas is in proportion to the strength or amount of the lytic filtrate employed.

4. The lytic agent for pyocyaneus is transmissible from tube to tube in series, but lysis is not produced as easily as in the case of D'Herelle filtrates. The pyocyaneus lytic agent does not destroy all the organisms in the tube. Many survive to form the secondary, or resistant strain.

5. This resistant strain is different from the original culture. It is non-pyocyanogenic, less spreading in its growth, and weak in its power to digest milk, gelatin and fibrin. It may be non-motile. It is not affected further by the lytic agent.

6. The lytic strain on the other hand maintains a high degree of intensity in all of its physiological reactions, and retains its motility.

7. When the lytic filtrate is brought to bear on various pyocyaneus cultures, they appear to be either sensitive (S-type) cultures or resistant (R-type) cultures. Strains which can regenerate the lytic agent may be referred to as lytic or lysogenic type (L-type).

8. An S-type culture under the action of the lytic agent is developed into an R-type corresponding in its essential characters with the R-type of the original pyocyaneus culture.

9. The lytic agent in broth is destroyed by heating at a temperature of 76° C. for thirty minutes. This temperature also destroys the gelatin-liquifying power of the filtrate, due to the enzyme, protease.

10. The lytic power of the filtrates maintains their activity in tubes at least for many months.

These results from the study of the lytic phenomenon of pyocyaneus are regarded as demonstrating that this case is similar in its essential features to the lytic phenomenon described by Twort, and also with the lytic phenomenon described by D'Herelle. The chief differences between it and the D'Herelle lysis is that the pyocyaneus lysis is a low-speed reaction. But they are both determined by the same ultimate cause. What this cause may be is not at present understood.

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IMPROVED PROCEDURE OF KAHN PRECIPITATION TEST FOR SYPHILIS

R. L. KAHN

The precipitation test for syphilis proposed by the author [1] called forth favorable comment from Keim and Wile,[2] Herrold,[3] Young,[4] Ide and Smith [5] and others.[6–7] Since the publication of the preliminary studies, however, several observations have been made which led to some changes in the original procedure; also, a modified technic has been evolved which is employed as a check on the original one. The improved method discussed in the following résumé embraces both the original and modified procedures.

THE ANTIGEN

Preparation of Alcoholic Extract

Beef heart is freed from fat and fiber in the usual manner and passed several times through a meat grinder. It is then spread on a platter and dried by means of a revolving fan. The dried plates are broken up into small particles and ground in a mortar or coffee grinder. The ground muscle is then extracted with ether at ice-box temperature until supernatant ether is free from coloring matter. Between three and four

[1] Kahn, R. L., *Arch. Derm. and Syphil.*, 5: 570, and 734; 6: 332. 1922.
[2] Keim, H. L., and Wile, U. J., *J. Amer. Med. Assn.*, 79: 870. 1922.
[3] Herrold, R. D., *J. Amer. Med. Assn.*, 79: 957. 1922.
[4] Young, C. C., *J. Amer. Med. Assn.*, 79: 1674. 1922; *Amer. J. of Public Health*, 13: 96. 1923.
[5] Ide, S. and Smith, G. J., *Arch. Derm. and Syphil.*, 6: 770. 1922.
[6] Holmes, J. A., *J. Mo. State Med. Assn.*, 19: 479. 1922.
[7] Levin, Wm., *J. Kans. State Med. Assn.*, 23: 4. 1923.

ether extractions will bring this about. At the end of the final extraction, the ether is filtered off and the ground muscle dried for some hours at room temperature until free from ether odor.

Given quantities of dried material are placed in Erlenmeyer flasks. A quantity of 95 per cent alcohol equivalent to five times the amount of dried material is added to each flask. The extraction is carried out in the ice-box from nine to ten days. After that period, 10 c.c. of supernatant extract is pipetted into a large test tube and the color compared either with some antigen that is known to give good results or with the following approximate color standard:

1. A solution is prepared containing 0.5 gm. potassium bichromate ($K_2Cr_2O_7$) in 100 c.c. distilled water (permanent standard solution). 2. One c.c. of this solution is mixed with 75 c.c. distilled water. 3. Ten c.c. of solution 2 is measured into a tube of the same size containing the extract to be tested and the colors compared.

If the amount of coloring matter in the new extract is weaker than in the standard, room temperature or incubator temperature for some hours or overnight may be resorted to until coloring matter is brought up to that contained in the standard. If the color of the new extract is the same or more intense than the standard, the extraction may be considered completed. The extract is now filtered off and is kept in the dark at room temperature as stock solution. This extract will keep for at least a year and possibly for many years.

Antigen prepared from ground heart muscle kept for some weeks or months does not give as sensitive results as that prepared from material freshly ground and dried. It has furthermore been observed that the non-specific sediments in negative sera following incubation of serum and antigen are due to impurities in the extract. These impurities are caused, in most cases, by excessive contact of the extract with cork or rubber stoppers.

The use of an alcoholic non-cholesterinized antigen for this test has been discussed in previous studies. Further investigations are under way. At present, in routine work, the use of a

cholesterinized antigen only is recommended and the procedures discussed below apply to this type of antigen.

Cholesterinization of Antigen

A given amount of extract is measured into an Erlenmeyer flask and a quantity of cholesterin added to render it a 0.4 per cent solution. The cholesterin is dissolved by warming in a water bath with gentle rotation. The solution is then filtered to remove impurities and is ready for use.

It is well to cholesterinize amounts of extract which will be likely to last for about a month or two only. Such extracts show a tendency to become slightly less sensitive on prolonged standing.

If a given extract is incapable of holding in solution 400 mg. of cholesterin per 100 c.c. at room temperature, the mixture should be kept in the incubator in the dark and the tendency of the crystallization of the cholesterin will thus be avoided.

PROCEDURE I (ORIGINAL)

Dilution of Antigen for Tests

The following method of diluting the antigen with salt solution is somewhat simpler than that described in the earlier communications:

1. The amount of antigen required for the tests is measured into an agglutination tube of about 0.8 cm. diameter.
2. Three times the amount of salt solution is added to a similar tube.
3. The saline is poured into the antigen tube with reasonable rapidity and the mixture is immediately poured back into the original antigen tube.
4. This mixture which is opalescent and shows no signs of turbidity is now ready for use, although there is no harm in further mixing back and forth.

The Test

Three tenths c.c. of serum previously inactivated for half an hour at 56° C. is measured into a small tube and 0.05 c.c. of antigen-salt solution mixture is added to it, and shaken for about a minute or more. Known positive and negative sera should be used as controls. The tubes are observed for spontaneous reactions and the final results are read after overnight incubation at 37° C. Best results are obtained with sera that are comparatively fresh and clear, and to which sheep cells (for removal of natural amboceptor) have not been added. A serum control consisting of 0.3 c.c. of serum with 0.05 c.c. salt solution should accompany each test.

Increasing Sensitiveness of Test

If an antigen, after testing with a number of syphilitic sera, appears to lack sensitiveness, the following simple steps will help overcome this difficulty: 1. The salt solution is chilled by keeping it in the ice-box before mixing with antigen. This renders the final antigen-salt solution mixture somewhat less stable than mixtures prepared with salt solution kept at room temperature. 2. Instead of mixing 3 parts of salt solution with 1 part of antigen, 2.5 parts and, in isolated cases, 2 parts of salt solution are mixed with 1 part of antigen. This increases the instability of the final mixture with reference to precipitation.

With most cholesterinized antigens, 3 parts of salt solution represent the minimum amount which will bring about an opalescent mixture. In some cases, however, 2.5 and even 2 parts of salt solution may still produce an opalescent mixture and may therefore be used with safety. The important thing to keep in mind is that the antigen-salt solution mixture used in the tests must show no signs of turbidity. An antigen mixture showing even slight turbidity at the time of using in the tests will be likely to give false weak reactions.

PROCEDURE II (MODIFIED)

Dilution of Antigen for Tests

1. A given amount of antigen (depending on number of tests) is measured into a small tube and an equal amount of salt solution is added to it from a tube of similar size.
2. This is mixed and centrifuged for about ten minutes — until the supernatant fluid is practically clear and a white precipitate is settled on the bottom of the tube.
3. The supernatant fluid is poured off and discarded and the amount replaced with salt solution. (Ex. 0.5 c.c. antigen is mixed with 0.5 c.c. saline and centrifuged. Supernatant fluid is poured off and 1 c.c. saline added.)
4. On mixing, the precipitate is redissolved in the salt solution forming a milky opalescent mixture with no trace of a precipitate. This mixture is then ready for use.

The Test

Three tenths c.c. of serum, previously inactivated for half an hour at 56° C., is measured into a small tube and 0.05 c.c. of new antigen mixture added to it. The tube is shaken for about a minute. Practically all tubes will become slightly cloudy, but those showing spontaneous reactions will show definite precipitations in clear serums. The final reading in this case also is taken after overnight incubation at 37° C.

Increasing Sensitiveness of Test

Instead of adding salt solution to antigen in the following proportion: — antigen : salt solution = 1 : 1 as outlined, it will be found in some cases that one may mix as follows: — antigen : salt solution = 1 : 0.75 and still obtain an opalescent solution on mixing salt solution with the precipitate formed after centrifugation. In such cases, the latter mode of mixing antigen with salt solution will give more sensitive results; so sensitive indeed in many cases that questionable reactions may safely be considered negative.

It is to be remembered, however, that in isolated cases, it may be necessary to mix in the following proportions: — antigen : salt solution = 1 : 1.25. The final antigen-salt solution suspension which is added to the serum, while milky, must be opalescent and entirely free from any suggestion of a precipitate.

THE READING OF RESULTS

The results are read in accordance with the following scale:

1. One or more large clumps = ++++.
2. Large sized flocculi = +++.
3. Moderate sized flocculi or granules = ++.
4. Small flocculi or granules = +.
5. Very small flocculi or granules = ±.

It is recommended in reading the results that all tubes showing the presence of definite clumps or heavy precipitates in both procedures, be first picked out and set aside in a special rack. These are the definitely positive reactions (++++ and +++) and can be read with very little difficulty. The remaining tests carried out with Procedure I are read as follows: 1. Slant the tube to such an extent that it is almost horizontal. This causes the fluid to spread into a thin layer. 2. Hold the slanted tube some inches above the level of the eyes. 3. Focus against some dark object such as the lower part of a window shade. 4. Observe whether the thin layer of fluid is entirely clear or has fine particles evenly distributed. When employing older serums, one will occasionally encounter precipitates settled on the bottom of the tubes. These are serum precipitates and will be present also in the serum controls. Furthermore, slight shaking will render these precipitates quite invisible.

All remaining tubes of Procedure II receive one c.c. (or 1.5 c.c.) of salt solution each and rack is gently shaken and permitted to stand about ten minutes. The negative tests show opalescence while the positive tests show the presence of precipitates. At this time it is well to add the same amount of salt solution to the serum controls and thus eliminate the

questionable precipitates due to the suspending of the serum sediments in salt solution. The latter may occasionally be used with advantage also in diluting some tests carried out with Procedure I.

The results of the two methods outlined check very closely. In isolated cases where there is disagreement, the average finding of the two methods is taken as the final results.

Although the final results are read after overnight incubation, it will be found that the strongly positive serums either react spontaneously after adding antigen or show the presence of definite precipitates after several hours incubation. From fifteen to seventeen hours is more than ample for incubation. Prolonged incubation beyond these hours is to be avoided. An element which will give false weak reactions, particularly after prolonged incubation, is the employment of tubes which will permit considerable evaporation of the serum during the incubation period. Agglutination tubes having an inner diameter of about 0.8 cm. will give best results. Any procedure which will reduce the element of evaporation during the incubation period will be found to improve the test. In this laboratory we place the racks in sealed copper containers and add wet sponges to supply moisture. By this means evaporation is reduced to a minimum.

We have not found it necessary to employ sterile salt solution. Chemically clean but not sterile precautions are required in this test.

Since the presentation of this paper additional improvements have been evolved in this test. Those interested are referred to *Rapid Precipitation Phase of the Kahn Test for Syphilis, Journal of the American Medical Association*, 81: 88, 1923.

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THE QUANTITATIVE ESTIMATION OF BACTERIOPHAGE

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THE many sources of the bacteriophages or lytic principles show that they vary in their nature. They may attack one or another species of bacteria, or, what is more common, vary in their attack upon different strains of the same species. Furthermore, they may vary in potency, energy content, or virulence. It is hence desirable that there be some means of measuring the lytic power of these lytic agents.

In the lytic principle it seems probable that we are dealing with a colloidal unit. As arguments for this might be advanced four experimental facts:

1. If an agar slant or plate be inoculated with a sufficiently heavy mass of culture of a strain attacked by the lytic principle, together with a small amount of this lytic principle, there are produced circular areas where no growth occurs.

2. If an agar tube be mixed, while still liquid, with a small amount of lytic principle, and then slanted and inoculated with a small amount of culture, so small that individual colonies will be developed, some of these colonies will be not circular but "pie-shaped," as it has been expressed, i.e., circular with a sector removed. It would seem that the colony in developing normally had encountered some sort of an inhibiting unit localized at the focus of the lysed or inhibited sector.

3. D'Herelle has mentioned ultramicroscopic granules which suggested themselves to him as being related, at least, to the bacteriophage, inasmuch as they seemed uniform in size, and numerically in a ratio proportional to the potency of the bacteriophage he was examining.

4. The presence of bacteriophage may be easily demonstrated in a dilution of a trillion of a potent strain of bacteriophage. If we should, as may easily be done, take a bacterial suspension in a concentration of a trillion organisms per cubic centimeter, and make dilutions in broth, there would be growth in a one to one trillion dilution of the suspension, indicating the presence of bacteria in that dilution. On the other hand a *ten millionth normal* solution of HCl or of NaOH is considered to be practically equal to water; that is, this dilution is too

FIG. 8. Sketch illustrating the lines of colony development of a Shiga dysentery meeting an anti-Shiga lytic principle unit.

great to show the effective presence of HCl or of NaOH. If we calculate from the number of particles in an ordinary colloidal solution, it may be shown that the concentration per cubic centimeter of these particles is of the same order as is shown by the limits of dilution in which the presence of lytic principle may be demonstrated; that is, about one trillion.

There are other arguments which bear out the particulate structure of the bacteriophage.

In the present work estimates of the numbers of bacteriophage units have been secured by two means, neither of which is original, with fair success.

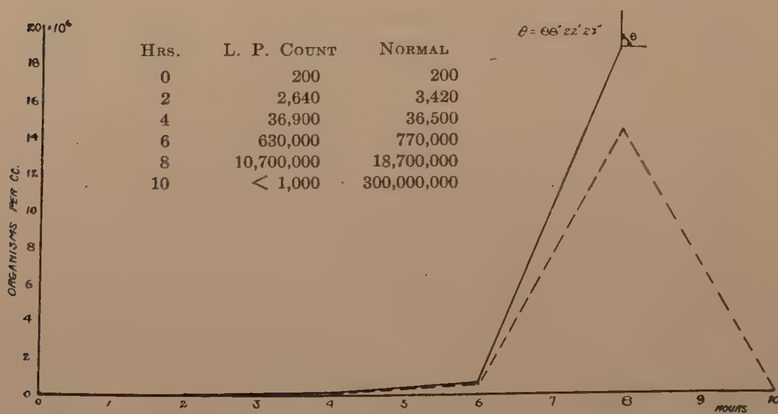
The first of these means involves mixing a known amount of lytic principle with a heavy suspension of bacteria and inocu-

lating to a sterile poured agar plate, which has been dried to eliminate excess moisture, spreading the inoculum and thereby fixing the mixture of lytic principle and organisms to a definite spot on the solid surface. In repeating D'Herelle's experiments in which he used *varying concentrations of organisms* and the *same amount of lytic principle*, the concentration of bacterial suspension was shown to have made no difference. Nine young agar slants of culture were washed up in about 30 cubic centimeters of broth, and dilutions made of this suspension with broth from 10 per cent to 100 per cent. To each tube was added the same amount of bacteriophage and a constant amount of the mixture was inoculated to plates. About 400 lytic areas developed on each plate, regardless of the concentration of organisms. Furthermore, by repeating the converse of the above, as was done by D'Herelle, and using a *uniform bacterial suspension* and *varying amounts of lytic principle*, the number of areas may, with care, be secured roughly proportional to the amount of lytic principle added. The variation from the mean was from 10 per cent to 40 per cent; that is, a count of 60 areas was secured where 100 was the expected result, at a maximum error.

The second means of enumeration is a dilution method. This consists of making up a series of dilutions in broth, 1:10, 1:100, 1:1000, and so on, of the lytic principle, and then inoculating with a very small amount of young broth culture which has been transferred so often that all the organisms are working at a maximum speed. Although it shows itself more sensitive than the area test, it is more doubtful for this reason, that it does not fix a bacteriophage unit in one spot and force it to demonstrate itself at that spot. In this method of enumeration we are dealing with two variables working simultaneously: first, the organisms which, while unattached by the bacteriophage, increase at the normal rate; second, an increase in bacteriophage developing by the lysis of the organisms. It is evident, however, that in a tube where there is some lytic principle, possibly a single unit, the lytic principle *will* triumph and the final result will be a clear tube. In the next higher

dilution of bacteriophage there will be no inhibition whatsoever, and the tube will show a normal growth.

A study of this variation between culture and bacteriophage has been a part of our work, but is as yet incomplete. A typical curve of the concentration of organisms exposed to the action of lytic principle will suffice:



Hrs.	L. P. Count	Normal
0	200	200
2	2,640	3,420
4	36,900	36,500
6	630,000	770,000
8	10,700,000	18,700,000
10	< 1,000	300,000,000

Fig. 9. Sketch illustrating the life curve of normal Shiga dysentery as compared to the life curve when exposed to a small amount of lytic principle (broken line).

The culture within a lapse of two hours has reduced the concentration per cubic centimeter from ten million to less than one thousand: bacteriophage has exerted a rapid and potent action.

It may be of interest to insert here a note upon the lag period. If we assume that the organisms multiply periodically by binary fission, N being the number of organisms inoculated into a tube, and t being the time elapsed from the inoculation (using as a unit of time the periods between binary fission), then C, the count at time t, is equal to $N \times 2^t$, or $C = N \times 2^t$. Whence $\log C = t \log 2 + \log N$, C and t being variables, the equation of a straight line. In our experiments, in using a culture which is frequently transferred, this law is born out:

the logarithm of the count plotted against the time is a straight line, and there is no lag period. The organisms continue their regular rate of multiplication.

The two methods of enumeration, the area and the dilution methods, do not check each other perfectly. There exists a discrepancy, the area counts being too low to account for the results secured by dilution. In an actual comparison experiment the area count indicated a concentration in our lytic principle of 8,000,000 units per cubic centimeter, whereas the dilution method showed the presence of lytic principle in a 1 : 100,000,000 dilution with none in the next dilution, 1 : 1,000,000,000, thus indicating a concentration of between 100,000,000 bacteriophage units per cubic centimeter and 1,000,000,000 per cubic centimeter.

There exist two very plausible explanations for this discrepancy, the first reasoning that the area count is too low, and the second that the dilution results indicate too high a concentration.

The lytic areas are of varying size as secured by different bacteriophage strains on different organisms, and may become so small as to be doubtful. They very likely in some instances are too small to be shown at all, and hence the count of lytic areas would be too low.

As another possible explanation of this discrepancy it must be observed that if we take, for example, a suspension of microörganisms containing 8,000,000 per cubic centimeter, theoretically we should have in a tube representing a dilution of 1 : 1,000,000 just eight organisms. Suppose these to be in ten cubic centimeters of broth, and we remove one cubic centimeter for the next dilution. The probability is, mathematically, 4 to 5, that we get an organism in the next tube, in which case we should get growth, and we should conclude offhand that there were between 10,000,000 and 100,000,000 organisms per cubic centimeter in the original suspension, — a conclusion altogether wrong. This chance may not be lost sight of, nor can it be forgotten that the laws of chance hold good only in a large number of cases.

There are several other possible explanations of the discrepancy between the two methods of enumeration.

In summary, we may say that there is evidence that the bacteriophage is a colloidal particle, two methods of enumeration being given. We are at present concerned with the discrepancies of enumeration, and with the quantitative aspects of phenomena involving lytic principle action.

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THE RELATIVE RELIABILITY OF INTELLIGENCE TESTS AND TEACHERS' MARKS

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If two persons mark an Alpha army intelligence test paper, the two marks will be identical or will vary only slightly from each other. If two teachers, or other persons, mark an oral recitation, or an ordinary examination paper, their marks are likely to deviate surprisingly from each other. One of the first and most conspicuous results of the recent development of educational measurement has been the demonstration of the unreliability of teachers' marks. One of the first and one of the most striking demonstrations was the experiment of Starch. Starch sent two papers in English to one hundred and forty-two different English teachers for their judgments of the degree of excellence. One paper was marked 64 by one judge, and another judge marked the same paper 98. Paper B was marked 50 by one, and by another 98. Thinking that possibly it was the subject-matter that accounted for the wide variation, he sent one mathematics paper to one hundred and eighteen teachers of mathematics. One teacher marked it 28 and another teacher marked it 92. No such variation in marks will ever be noticed in marking any good intelligence test.

I have presented on two separate occasions to this body the results of the attempts of several classes to mark penmanship papers. The ranges run about like this: 55—93; 34—81; 40—100; 60—100; 55—95; 20—100; 20—90; 52—100; 75—100; 70—100. No one ever found such discrepancies when marking an army Alpha, Otis, or other good intelligence test. If we are to judge the reliability of the two kinds of tests by the degree

of approximation to each other that different markers attain, there can be no ground for argument. The superiority of the tests is self-evident.

If we employ the definiteness of the thing that is measured as a standard of comparison, the superiority of the test is equally evident. The army Alpha test measures the ability to answer that kind of questions and that is all that it professes to measure. What the teacher's marks measure is a matter of such indefiniteness that no one is able to describe it. Generally, it is said that teacher's marks measure the ability to do school work; but whether the school work that is meant is arithmetic, drawing, penmanship, gymnastics, or any one of twenty other lines of endeavor, no one can say. Even if we make a list of all the subjects in which a teacher gives marks, there is no probability that the series of marks opposite the names of any two pupils on the school records will indicate anything like the same series of subjects. The superiority of the test in definiteness is incontrovertible.

Generally, however, the test is compared with the school performance of the pupils, and its reliability is judged by the degree of correspondence between the results of the test and the school marks. The test thus becomes a means of judging what the future performance of the pupil in school will be, and the marks are used as a standard by which to judge of the validity of the test. The test is commonly judged by its prognostic value, with the marks serving as a standard of the success or failure of the pupil in his work beyond the period of his school activities.

It is this standard of reliability that I wish to consider principally today, under the term of the relative reliability of intelligence tests and teachers' marks. It is around this applicability of the results of tests that most of the criticism of test results have recently centered. Most conspicuous of these criticisms of the past year has been Mr. Bagley's article on the *Educational Determinist*, although many others seem to be back-pedaling on mental and educational measurements as rapidly as possible.

Typical of the criticisms recently published is that of Mr. J. Crosby Chapman, of Yale University, who says that "By a simple process of statistical analysis, a formula has been derived to measure the extent to which our present instruments (tests) are adequate to measure this difference between mental and educational standing. Applying this formula to the usual run of mental and school tests it is immediately apparent that the so-called mental-educational differential index possesses almost no reliability whatever."

In the first place, I wish to call attention to certain facts which are not at all in agreement with this dictum of the critic of mental tests, and to inquire in the light of such facts if there is not good reason for him to inquire into the validity of his simple process of statistical analysis. Secondly, if the agreement between the results of mental tests and school standing is not so great as one has reason to think it ought to be, which one of the pair of measures is principally at fault?

We have been inclined to test our mental measures by their agreement with school standings, or teachers' marks; but may it not be largely the fact that there is not a close agreement between the two that constitutes one of the principal advantages of the tests? Is it not true that in the capacities that are employed in learning, and in doing any kind of school work, the mental tests furnish a much more reliable basis of judgment, and constitute a standard by which the validity of the teachers' marks may be measured?

I wish to make use of the results obtained by giving the Alpha army tests to 1572 Normal College students last year, and also the scholastic records of the same students recorded on the books of our institution for the fall and the spring terms. I do not claim a high degree of accuracy for the results of the army test. They were given at different times by different teachers, and some of the students had taken the same test on some previous occasion. But however much the results of the test may be lacking in accuracy, I feel sure that they are decidedly less subject to error than are the marks given by the teachers in the usual way and recorded on the books of the

institution. The marks for each term for every pupil were averaged by assigning arbitrary values to each letter of the record, and including every mark recorded for every student. Every A was called 100; every B, 90; every C, 80; every D, 70; every E, 60; every F, 50. Some students had seven marks, others only three.

In the army tests, the average of the 1572 students was 134.5. The 276 men averaged 137, the 1296 women averaged 134. In the spring term school record, the entire 1333 averaged 82.4 with an average of 83 for the women and 80.1 for the men. Notwithstanding the fact that the mental tests do not profess to measure the willingness to work, which is quite as important to school success as is the intelligence which the tests measure, nor the conditions under which the work is done, there is considerable agreement between the school record and the army test. The 59 students with an army test record of from 180 to 199 averaged in the school record 89.3, while the 79 persons with an army test record below 90, averaged only 77.9 in the school record, or on the letter scale a difference of from less than C to nearly A. To reduce it to a really per cent basis, there would be disclosed a difference of nearly 23 per cent in the average of the two groups.

When we pick out individual examples, we shall find considerable corroborative testimony. Mary A. had a school record for three terms of 57, 65, 50. Her army test record showed 159. Incredulity led to an examination of her army test paper, and a clerical error accounted for the report of 159 instead of 59 as it should be. One man showed an average school record of 100. His army test indicated 107. Incredulity again led to an examination of his papers, when it was found that the report should have been 187 instead of 107.

But the relation is not very great. A computation of the coefficient of correlation between the results of the army tests and the school records shows a correlation of .236 for the spring term and of .269 for the fall term. This is low and would be of doubtful validity were it not for the large numbers involved. The assumption is generally made that, in order to

insure a real relation, the coefficient of correlation must be three or four times as great as the probable error. In this case, the amount of correlation is about twenty times as great as the probable error, which would seem to insure a high degree of reliability for the coefficient.

When we compute the coefficient of correlation between the fall term school record and the spring term school record, we get some wholly unexpected and surprising results. One would think that when we have the school record for two successive terms, made by the same students, marked by the same teachers, in the same set of subjects, we ought to get a high correlation. Such is not the case. The coefficient for the fall and spring terms is .326, an increase of only 9 per cent over the correlation between the army test and the spring term record, and of only 5.5 per cent over the correlation between the army test and the fall term record. The probable error again is about one twentieth of the amount of correlation.

Without assuming to be able to demonstrate the fact from this single case, and recognizing that the data are not very accurate, I am inclined to believe that the 9 per cent increase of correlation of the school marks over the correlation between the army test and the school marks represents about the amount of the correlation which is due to the teacher's marks. Since the factors measured by the army tests occur in the abilities that contribute to success in school work, I am inclined to believe that the 9 per cent in one case and the 5.5 per cent in the other measures the actual correlation between the teachers' marks for the two terms. Assuming that this is so, the army tests are about two or two and a half times as reliable a measure of the student's ability as is the school record. The test record is a much more serviceable report for an employer or a superintendent to be furnished with than is a school record.

I do not attribute very much value to the determination of the amount of relation between these two measures. The results from the army tests confessedly involve considerable error, all of which however is in the direction of diminishing the degree of relationship. But a much greater amount of

error must be attributed to the school record. School work is an indefinite term, and may mean the records from any four or five or six courses selected from a list of fifty or more. Add to this the demonstrated inaccuracy of the marks of every teacher, no one of which can be checked up by a comparison with any other estimate or measure, and it will readily be understood that two or two and a half times is a low estimate of the unreliability of teachers' marks compared with the results of intelligence tests.

In the computation of the correlation, I have used the Spearman foot-rule method, as about the only one available for such large numbers. Many persons prefer the Pearson product-moment formula, which takes into account the amount of differences as well as the rankings. Translating the Spearman results into Pearson terms by means of a table, we get somewhat higher correlations. Between the army test and the spring term record the correlation is .392. Between the army test and the fall term record it is .444. Between the spring and the fall terms records it is .522. The probable error is about the same, .0174. The excess of the relation between the two school terms and the army test and the school record is only slightly less.

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MENTAL MEASUREMENTS AND PURE SCIENCE PSYCHOLOGY

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In the following discussion we have tried to indicate the relation between mental measurements and pure science psychology. Also we have raised the question as to whether or not an introductory course in mental measurements should stress the pure science aspects of the work rather than the applied aspect, such as solving practical problems of classifying children for differential teaching, selecting men for "jobs," giving vocational guidance, and the like. A series of minor points arises under these general considerations.

Our first thesis is that mental measurements, in the best sense of the term and also genetically, *is* pure science psychology. All psychology undertakes to measure mental processes and capacities. At the same time we are aware that many courses in mental measurements are so conducted as to be definitely classed as applied psychology. The student's attention is forced upon solving practical problems rather than studying the mental processes and methods of measuring them adequately in and for themselves.

Our second proposition is that an introductory course in mental measurements may be classified today as pure science psychology or as applied psychology — all depending upon which aspect is emphasized by the instructor. If the course lays emphasis upon (1) careful and persistent attempts at understanding the nature of the psychological process or capacity involved, (2) consideration of present and new methods of measuring those capacities, and (3) the establishing of norms for classification, then the course is in essence a pure science course. If the course consists in becoming acquainted with

various tests and practice in giving them, with emphasis on their practical value, then the course is essentially applied psychology. Of course it is largely a matter of emphasis in either case, but the emphasis appears to the writer to be extremely important. Most courses in mental measurements are taught as applied psychology.

Our third proposition is that a general introductory course in the psychology department of a university or college should emphasize the pure science aspects of the work. The course should ideally demand a preceding course in general psychology text and laboratory. The student should be constantly confronted with the problem, *What are we testing?* Instruments of precision and even complicated apparatus may have to be studied and used. A scientific attitude and a thorough understanding of psychological methods of "measuring" and controlling conditions are to be emphasized. If such emphasis on exact work and ideals drives out half of the students, let us be thankful for the fact. The remaining half will be worth while and really trained to tackle practical problems if they ever turn that way. Pencil and paper research alone is to be discouraged.

Another fact needs emphasis, viz., that a course in mental measurements is not merely a course in testing general intelligence. In fact G. I. tests are but a minor part of a course in mental measurements. The measurement of special processes or capacities (simple and more complex), including affective and emotional aspects; is very important.

Mental measurements have added to or supplemented the older psychology by insisting upon norms and classifying persons according to the amount of possession of a trait or capacity. In the older psychology, if a phenomenon was observed in the case of a few individuals (or even one) as a result of careful experimentation, a law was formulated or a fact of consciousness or behavior was declared. Obviously before people could be classified a standard or norm had to be established. This was seldom done and about all the psychologist could say was, "Here is a phenomenon! It exists because I have found

it manifesting itself in at least one individual!" More than this he could not say. The newer psychology goes on and tests many individuals, finds the average performance, establishes norms, and classifies people. This matter of classification is an important business of any science and, in psychology as elsewhere, there must be not only a technique for quantitative measurement but established norms.

The objection that the man in mental measurements does not know specifically the nature of that which he is testing is not a valid criticism against his work. Because of the emphasis on practical aspects of tests, the mental tester has all too often forgotten to trouble himself enough concerning the nature of that which he is testing. Now if one is interested merely in solving practical problems then he need not trouble himself much about the nature of what he is testing. If he devises tests which solve problems his work is a success. The man of pure science, however, must first and foremost concern himself with the nature of the processes or traits involved. The student should be impressed with this same necessity for psychological analysis.

On the other hand any criticism to the effect that mental measurement workers do not know the exact nature of that which they are measuring is, so far as it is true, merely a criticism against any and all psychology. The mental processes are so intricate, so interrelated, that one cannot isolate any one and work with it alone. At best the psychologist can only say, "I am testing chiefly this or that." Even the exact nature of the simpler psycho-motor processes is often in dispute, for careful study shows them to be relatively complicated and involving the higher central processes. When one turns to the more complicated processes of association, retention, attention, judgment, reasoning, emotion, affection, and what not, it is even more difficult to know the exact nature of what is being tested. One can only make a workable assumption as to the nature of what is being tested. This assumption must be based upon historical discussion and experimental suggestion. Having made the best possible assumption one must then begin work. One

may "fire at random" at times. but in the end we shall know more about the thing we are testing.

An objection is often made that we should not use the term 'mental measurement,' but rather performance or behavior tests. Of course, any psychological measurement is directly a measure of performance or behavior. We infer the mental process or the conscious state. It seems better at the present time for us to keep the term 'mental measurement,' remembering that it means directly measurement of behavior.

In summary we may state, then, that our paper is a plea for a greater concern and interest in mental measurements as a pure science work rather than as emphasizing 'solving practical problems.' We believe that the introductory course in mental measurements should devote more time to a study of the nature of the processes being tested and that the technique (present and historical) of measuring should be carefully drilled into the student. We should largely discard the method of "testing the test" by comparing it to practical criteria. In the best and genetic sense of the term we believe that mental measurements are to be classed under pure science psychology. At the same time there seems to be a good deal of pseudo-science parading under the name of mental testing.

University of Michigan

THE SNAKES OF THE GENUS VIRGINIA

FRANK N. BLANCHARD

CONTENTS

The considerable difficulty attending the identification of a small and somewhat aberrant specimen of *Virginia elegans* led to the accumulation of so much more information on the variation and distribution of the genus Virginia than was elsewhere available that an assembling of the results in permanent form has seemed desirable.

The snakes of this genus were first made known by Baird and Girard in 1853, only about seventy years ago. To their secretive habits and apparent scarcity must be attributed this late recognition and our present almost total lack of knowledge of their natural history and environmental relations. Attention to these latter facts should be enough to impel all who have the

opportunity for observing these snakes to put in permanent form any information they can obtain.

Specimens for examination were loaned by numerous institutions and individuals, and it is a pleasure for the writer to record his indebtedness to Dr. Leonhard Stejneger and Miss Doris M. Cochran of the United States National Museum, to Professor A. G. Ruthven of the Museum of Zoölogy of the University of Michigan, to Dr. G. K. Noble and Mr. K. P. Schmidt of the American Museum of Natural History, to Dr. Thomas Barbour of the Museum of Comparative Zoölogy, to Professor A. H. Wright of Cornell University, to Dr. Eugene A. Smith, director of the Geological Survey of Alabama, and to Mr. H. P. Löding of Mobile, Alabama. The drawings were prepared by Dr. Frieda Cobb Blanchard.

Abbreviations of names of museums or collections are as follows:

Ala. = Museum of the Geological Survey of Alabama;
Amer. = American Museum of Natural History;
British = British Museum;
Cornell = Cornell University Museum;
Field = Field Museum of Natural History;
M. C. Z. = Museum of Comparative Zoölogy;
Paris = Paris Museum;
Mich. = Museum of Zoölogy, University of Michigan;
U. S. N. M. = United States National Museum.

GENUS VIRGINIA Baird and Girard

1853. VIRGINIA Baird and Girard, Cat. N. Amer. Rept., Pt. 1, Serpents, p. 127 (type species, *Virginia valeriae*).

Description. — The snakes of this genus belong to the family Colubridae and may be diagnosed as follows: maxillary teeth solid, about 19 or 20, small, subequal; mandibular teeth 20 to 22, small, becoming smaller behind; head small, neck not or but slightly distinct; eye moderate, with round pupil; no preocular; loreal and prefrontal entering eye; nasal divided,

nostril in prenasal; scales smooth or weakly keeled, in 15 or 17 rows, without apical pits; anal plate divided; tail short, caudals in two rows.

The cephalic plates are normal (See Fig. 10), consisting of paired parietals, prefrontals and internasals, and a single frontal between two supraoculars; the nostril lies chiefly in the anterior of the two nasal plates, not more than slightly indenting the anterior border of the postnasal; the long loreal tapering slightly forward is in contact anteriorly with the postnasal and posteriorly with the orbit; the upper anterior border of the orbit is formed by a postero-lateral extension of the prefrontal; postoculars, 1 to 3, more commonly 2, in which case the upper

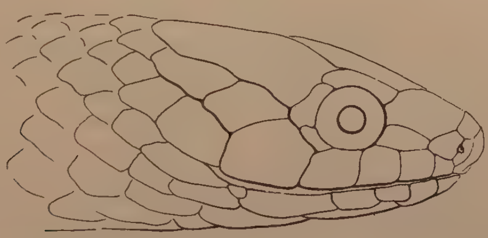


FIG. 10. *Virginia valeriae valeriae.* Side view of head. (A. M. N. H., No. 18073.) × 5.

is generally the larger; a single anterior temporal lying in the angle between the fifth and sixth upper labials, and narrowly in contact with the upper postocular or separated from it by the parietal and fifth upper labial (extreme positions shown in Figs. 11, 12); two posterior temporals, one directly behind the anterior temporal and the other between the upper posterior temporal and the last upper labial; upper labials normally six; lower labials normally six. The first lower labials meet on the chin behind the triangular mental plate, and are succeeded posteriorly by two pairs of elongated chin shields, the first in contact throughout their length, and the second diverging posteriorly. Into the angle formed by the diverging posterior chin shields fits the first ventral scute. (See Fig. 13.)

On the body are 15 or 17 rows of dorsal scales, wider on the lower row and narrower above, perfectly smooth or weakly keeled, and without apical pits. On the abdomen is a single series of large transverse plates, the ventrals, which vary in number from 111 to 131. These are terminated posteriorly by

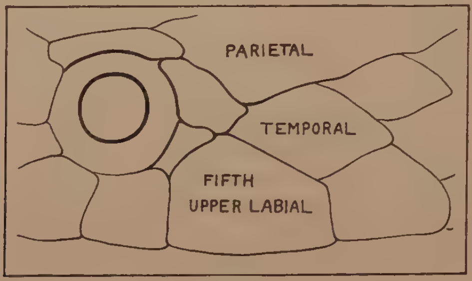


FIG. 11

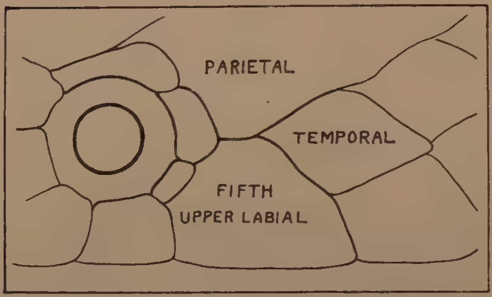


FIG. 12

FIGS. 11, 12. Sketches showing extreme positions of first temporal and adjacent scutes. Upper figure, *Virginia valeriae valeriae* (U. S. N. M., No. 52475); lower figure, *Virginia valeriae elegans* (U. S. N. M., No. 56222). × 10.

the divided anal plate. The plates under the tail, or caudals, are normally divided, but occasional individuals have a few of the anterior ones entire. They vary in number from 22 to 45.

The head is but slightly distinct from the neck, widest in the temporal region, and tapering forwards. The body is a little stout in build, the sides not meeting the belly in an angle. The

tail is short, and tapers quickly to a horny tip. It varies from .126 to .206 of the total length, being usually a little longer in males than in females, and also distinctly wider at the base.

The color is a dark brown or gray above and uniformly light below, without any noticeable pattern. Frequently, however, individuals show four longitudinal series of small dark dots, one series on each side of the dorsal median line (which may be

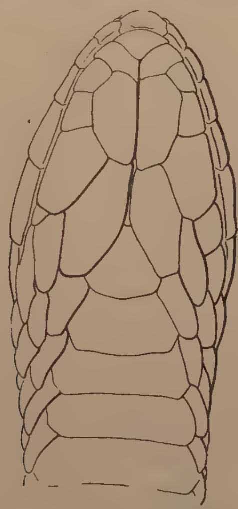


FIG. 13. *Virginia valeriae valeriae.* Ventral view of head. (A. M. N. H., No. 18073.) × 5.

perceptibly lighter than the general coloration above), and one series on each side at about the fourth row of scales.

The penial characters could not be satisfactorily determined because only one specimen had the penes well everted. Their description will be found under *elegans*.

The dentition, as indicated by a few specimens, is as follows: maxillary teeth, 19 or 20, small and subequal, in an uninterrupted series; mandibular teeth, 19 to 22, small, becoming smaller behind; palatine teeth, 15 to 20; pterygoid teeth, 14 to 25, diminishing a little posteriorly (See Table I).

Range. — The genus *Virginia* is known only from south-

eastern North America, from New Jersey to Missouri, and south into Georgia and central Texas (See Map III).

Habitat and Habits. — These snakes are secretive and seem to prefer timbered regions. They are ovoviviparous.

Variation. — The number of dorsal scale rows is usually constant from head to vent, and the variations that do occur are for the most part so sporadic and few that their significance is dubious. The normal number of rows in *elegans* is 17; but one individual of those studied has 19 rows along the middle of the body (for a distance of 33 scales on one side and 38 on the other), exhibiting thus the formula 17–19–17. In this case

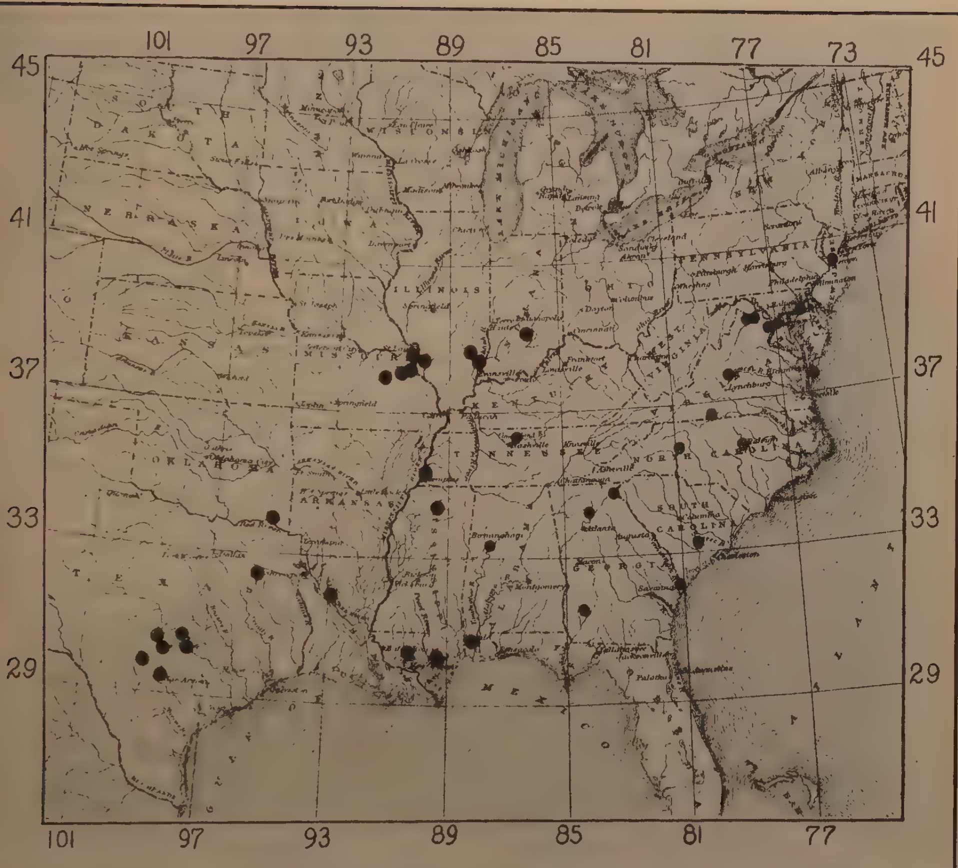
TABLE I

Number of Teeth in the Genus Virginia

Museum	No.	Form	Locality	Dentition							
				Maxillary		Mandibular		Palatine		Pterygoid	
				left	right	left	right	left	right	left	right
Mich.....	57711	elegans	Mobile, Ala......	19	19	19	19	15	17	23	25
"	57712	"	" "	19	20	22	22	20	19	20±	23
"	57713	"	" "	19	20	20	21	16	16	23	14±
U.S.N.M.	4482	"	South Illinois....	19	20	21	22				
"	6050	valeriae	Southeastern U.S.	20	19	22	20				
Paris.....	.....	"	South Carolina. .	22		....		20		25	

it appears to be the fourth row that is added on each side to make 19. A few individuals exhibiting brief interruptions to 15 rows make the change by loss of the third or fourth row on each side, but in others the change involves the seventh row. The change from fifteen to thirteen seems to involve the third row. Thus it appears that no rule can be derived as yet for change in number of scale rows.

The supralabials are 6 in every instance observed, except one (U. S. N. M., No. 56218) in which the change to 5 on one side involves the union of the third and fourth scutes. The lower labials are normally 6, but variations to 5 and 7 are not uncommon in both *elegans* and *valeriae.* The change to 5 was, in six of the instances observed, by a fusion of the last two, and



Map III. Map showing Locality Records of *Virginia valeriae elegans* (large circles) and *Virginia valeriae valeriae* (small circles).

in one by a fusion of the second and third. One specimen (A. M. N. H., No. 18073, Fig. 10) shows the fifth greatly reduced. Change to 7 was in five instances by the addition of a third, and in one by division of the fifth.

There is usually no preocular, but in one instance observed a small one is cut off from the prefrontal and in another the posterior end of the loreal is cut off. The postoculars are commonly 2, but variations to 1 and 3 are by no means unusual.

Other variations are discussed under each form and in the summary.

SUBDIVISIONS OF THE GENUS

Two distinct species of Virginia have hitherto been recognized, *V. elegans* with 17 rows of scales and *V. valeriae* with 15 rows. Numerous other differences mark these forms, as the detailed descriptions following will show, but the differences in each instance are average, the ranges of the two forms are contiguous, and specimens from near the common boundary present an intermediate condition even in the most constant difference between the two forms, — the number of scale rows. Thus the specimen from Tyree Springs, Tennessee, although possessing 15 rows of scales for the most of its length, has interpolated in five places on the right side and in one on the left a third or fourth row of scales for a distance in each case of from one to three scales in extent, and two of the three specimens from Mobile, Alabama, exhibit variations from 17 to 15 and even to 13. Were such variations scattered throughout the range of *valeriae*, they would be of less significance in this respect. As it is, with additional material, we may fully expect the constancy in number of scale rows to fail completely in the region of the common boundary of the ranges. These two forms are, therefore, regarded as only subspecifically distinct.

KEY TO THE FORMS OF VIRGINIA

Dorsal scales in 17 (or, rarely, 19) rows, usually keeled at least posteriorly.............................*V. valeriae elegans* (Kennicott). (Central Indiana to Missouri, south to Mobile and west to eastern Oklahoma and central Texas.)

Dorsal scales in 15 rows, usually smooth or only faintly keeled near the vent. . . . .*V. valeriae valeriae* (Baird and Girard). (Central New Jersey to Georgia and Alabama, and north into Kentucky.)

Virginia valeriae elegans (Kennicott)

1859. *Virginia elegans*, KENNICOTT, Proc. Acad. Nat. Sci. Philadelphia, p. 99 (type specimen probably lost, in which case U. S. National Museum no. 4482, sent by Robert Kennicott from South Illinois may be regarded as typical; type locality: heavily timbered regions of southern Illinois). — JAN, Archiv. Zoöl. Anat. Fisiol., vol. 2. fasc. 1, 1862, p. 24; Elen. sist degli Ofidi, 1863, p. 34; Icon. Gen. Ophid., livr. 12, 1865, pl. 2, fig. 6. — DUMERIL and BOCOURT, Miss. Sci. Mex., 1870, p. 544 (part), pl. 32, figs. 4, 4a. — COPE, Bull. U. S. Nat. Mus., no. 1, 1875, p. 35. — JORDAN, Man. Vert., 1876, p. 182. — SMITH, Geol. Surv. Ohio, vol. 4, 1882, p. 699. — YARROW, Bull. U. S. Nat. Mus., no. 24, 1882, pp. 13, 84. — DAVIS & RICE, Bull. Chicago Acad. Sci., vol. 1, no. 3, 1883, p. 29; Bull. Illinois State Lab. Nat. Hist., no. 5, 1883, p. 31. — GARMAN, S., Mem. Mus. Comp. Zoöl., vol. 8, no. 3, 1883, p. 98. — YARROW, Smiths. Misc. Coll., no. 517, 1883, p. 13. — COPE, Proc. U. S. Nat. Mus., vol. 14, 1891, p. 599. — GARMAN, H., Bull. Illinois State Lab. Nat. Hist., vol. 3, art. 13, 1892, p. 307. — HAY, 17th. Ann. Rep. Dept. Geol. Nat. Res. Indiana for 1891, 1892, p. 488. — BOULENGER, Cat. Snakes Brit. Mus., vol. 2, 1894, p. 289. — COPE, Ann. Rep. U. S. Nat. Mus. for 1898, 1900, p. 1007, fig. 271. — BROWN, Proc. Acad. Nat. Sci. Philadelphia, 1901, p. 83. — DITMARS, Rept. Book, 1908, p. 273. — STRECKER, Baylor Univ. Bull., vol. 12, no. 1, 1909, p. 8. — BRIMLEY, Proc. Biol. Soc. Washington, vol. 23, 1910, p. 15. — HURTER, Trans. Acad. Sci. St. Louis, vol. 20, no. 5, 1911, pp. 191, 255. — STRECKER, Baylor Bull., vol. 18, no. 4, 1915, p. 39. — STEJNEGER & BARBOUR, Check List, 1917, p. 98. — POTTER, Copeia, no. 86, p. 83.

1922. *Virginia valeriae elegans*, BLANCHARD, Occ. Pap., Mus. Zoöl., Univ. Michigan, no. 117, p. 14.

Description. — The scalation of the 42 specimens examined may be summarized as follows: ventral plates, 117 to 131 (males, 113 to 125, average, 121; females, 118 to 131, average, 126); caudals, 27 to 45 (males, 35 to 45, average, 39; females, 25 to 36, average, 31); supralabials, 6; infralabials, 6, rarely 5 or 7; prefrontal and loreal forming anterior boundary of orbit; rarely a preocular excluding prefrontal from orbit; loreal long and narrow; postoculars usually 2, occasionally 1 or 3; temporals, 1 + 2; posterior chin shields generally longer than anterior, diverging; scale rows, 17 throughout, rarely 17–19–17,

or with interruptions to 15 or 13; dorsal scales usually weakly keeled on more or less of posterior portion of body, rarely all smooth; lower rows wider than upper, lowermost the widest.

Body in large adults rather thick for its length, tapering gradually forward to the snout, although generally widened a little in the temporal region. Tail short, in males .173 to .206, average .191, of total length, in females, .127 to .182, average .151, tapering abruptly in females, more gradually in males. The largest specimen examined measured 316 mm. and came from St. Claire County, Illinois.

The general color above is dark brown or dark gray, with or without an inconspicuous median light stripe, about 2 scales wide, along the back, and frequently with four longitudinal series of small black spots; beneath, uniform whitish. The small black dots when present are spaced about one scale apart and form a line on each side of the median dorsal light stripe, generally between the second and third scales from the median row, and a second line on each side, generally between the fourth and fifth rows from the median one, and in alternation with the spots of the upper rows. Below these lower rows the dark dorsal color may either become more or less suddenly lighter or continue dark to the tips of the ventrals. The head is uniformly dark above or slightly mottled with black; the chin, lower labials, and lower portion of the upper labials, immaculate like the belly. Frequently there is a fine light line, lengthwise on each dorsal scale, whether a keel is present or not.

A living specimen from Covington, Louisiana, showed the following coloration (by comparison with Ridgway's *Color Standards and Color Nomenclature*). Argus-brown above, grading towards a carrot red on the lowermost row of dorsal scales and on the ends of the ventrals; a little lighter along the median dorsal line; head above darker, reticulated with black; lower surfaces nearly a sulphur yellow, except the chin and labial region which is rather lighter than an orient pink.

The copulatory organ on one specimen (U. S. N. M., No. 56222) is well everted and exhibits the following characters: organ slightly bifurcate at tip, sulcus single, leading between

two small confluent smooth areas at distal end; no calyces; small spines at top becoming gradually larger proximally; two large spines on each side of sulcus with a few smaller ones near each, one pair of the large spines near the sulcus and on the inner side, the other pair lateral and farther from it; basal half of organ with minute spines.

Range. — Central Indiana, Illinois, and Missouri south to Mobile and west to eastern Oklahoma and central Texas (See Map III).

In addition to the localities included in the list of specimens examined, the following records appear to be reliable: Mt. Carmel, Illinois (Cope, 1891, p. 599); Brown County, Indiana (Hay, 1892, p. 488); New Orleans (Cope, 1900, p. 1008); White Eagle Mine, Spring Creek, Burnet County, Texas (Strecker, 1909, p. 8); and Lindale, (Smith County, Texas (Strecker, 1915, p. 39).

The record for Brown County, Indiana, although very definitely stated and described, is one much in need of verification, for it gives an unexpected eastward extension to the range. H. Garman's record (1892, p. 308) of *valeriae* for Union County, Illinois, was more likely based on a specimen of *elegans*.

Habitat and habits. — The only references to this subject that I have seen were by Kennicott, who says that these snakes are found in the "heavily timbered regions of southern Illinois" and by Hurter (1911, p. 255) who remarks: "All I have found were under rocks. Once I caught one sliding over a narrow path in heavily timbered bottom lands." A specimen from Covington, Louisiana, kept by the writer for several months, fed readily upon earthworms.

Variation. — The series of specimens at hand is too small to demonstrate geographic variation within the range, but it may not be amiss to point out certain peculiarities not discussed elsewhere. In U. S. N. M. No. 27064 from Waring, Texas, the preanal scute is divided, and in three specimens, U. S. N. M. Nos. 28412 and 56222, and Cornell No. 7600, 7, 4, and 5 of the caudal scutes, respectively are entire instead of divided.

Keels on the dorsal scales are distinctly characteristic of *elegans*, but a comparison of the sexes in the extent of keeling is suggestive. Of 19 males, 17 have the keels well developed, 2 only faintly so, and none lack them entirely; while of 20 females only 11 have the keels well developed, 6 have them

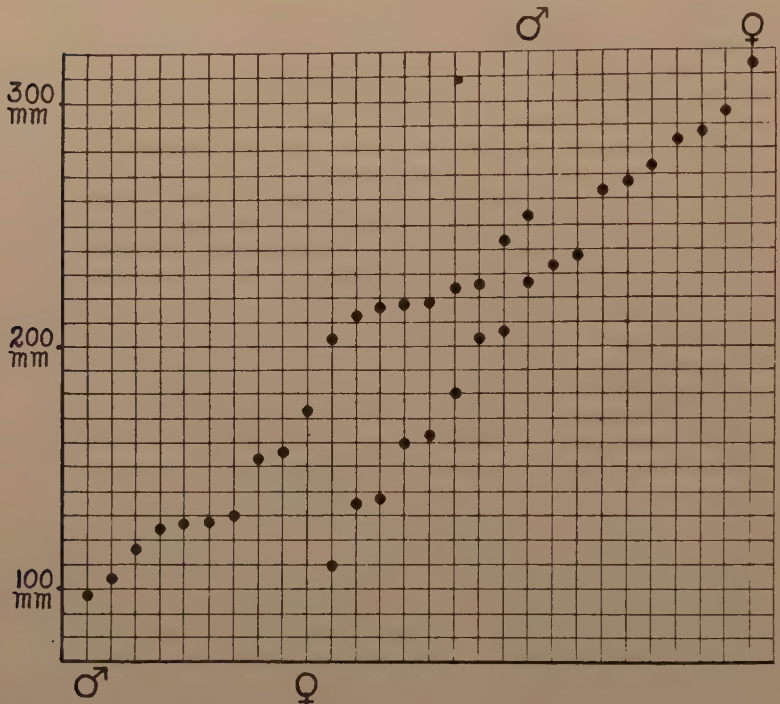


Fig. 14. Chart showing length in millimeters of each complete specimen of *Virginia valeriae elegans*.

faintly, and 3 not at all. It would appear that if, in this genus, keels are degenerating, the females are losing them the faster. This latter point, however, receives no support from the distribution by sex of the keels in *valeriae*.

The total lengths in millimeters of all complete specimens measured are shown graphically in Fig. 14.

List of Specimens of Virginia valeriae elegans

Museum	Number	Locality	From Whom Received	Sex	Scale Rows	Ventrals	Caudals	Supralabials	Infralabials	Oculars	Temporals	Total Length	Tail Divided by Total Length
Cornell.....	1973	?	?	male	17	123	37	6	5	0, 2	1 + 2	240	.195
"	4329	Bay St. Louis, Mississippi........	Brimley Brothers	female	17	123	29	6	6	0, 2	1 + 1	212	.146
"	7363	Chastine, Louisiana.............	....	"	17	120	29	6	6	0, 2	1 + 2 1 + 2	237	.152
"	7364	" "	....	male	17	114	35	6	6	0, 1 0, 2	1 + 2	116	.186
"	7381	" "	....	"	17	113	34	6	6	0, 3	1 + 2	126	.183
"	7395	" "	....	"	17	121	40	6	6	0, 3	1 + 2	130	.185
"	7600	?	?	female	17	123	32	6	7	0, 2 0, 3	1 + 2	201	.154
M. C. Z....	6714	Bay St. Louis, Mississippi.......	....	"	17	123	31	6	6 6	0, 2 0, 1	1 + 2	82	.159
Mich.......	53669	University, Mississippi...........	H. A. Dennee....	"	17	125	30	6	6	1, 2 0, 2	1 + 2	264	.144
"	57711	Mobile, Alabama................	H. P. Löding....	"	17	122	33	6	6	0, 1	1 + 2	161	.164
"	57712	" "	"	male	15–13–17	121	37	6	6	0, 2 0, 3	1 + 2	218	.193
"	57713	" "	"	"	13–15–17–15	117	38	6	6	0, 2	1 + 2	172	.204
"	57714	Covington, Louisiana............	P. Viosca, Jr.....	female	17	118	34	6	6	0, 1 0, 3	1 + 2	180	.182
U. S. N. M.	2055	Fort Towson, Oklahoma.........	Dr. Edwards.....	"	17	118	28	6	6	0, 3	1 + 2	207	.150
"	2055	" " "	"	"	17	124	25	6	6	0, 3	1 + 2	228	.136
"	4482	South Illinois..................	R. Kennicott....	"	17	130	33	6	6	0, 2	1 + 2	287	.157
"	13632	Helotes, Texas.................	S. W. Marnock...	male	(15–)17	119	37	6	6	0, 1	1 + 2	216	.194
"	13632	" "	" ...		17	[1]		6	7	0, 3	1 + 2	adult	
"	15335	" "	J. H. Clark.....		....	[2]							
"	20814	St. Louis, Missouri.............	J. Hurter........	female	17	131	27 +	6	6	1, 2	1 + 2	295 +	
"	22816	Liberty Hill, Texas.............	H. H. Thorpe....	"	17	127	27	– 6	.. ..	— 0, 2	— 1 + 2	284	.127

[1] Anterior end only.

[2] Specimen in bad condition, — unidentifiable.

LIST OF SPECIMENS OF VIRGINIA VALERIAE ELEGANS (*Continued*)

Museum	Number	Locality	From Whom Received	Sex	Scale Rows	Ventrals	Caudals	Supralabials	Infralabials	Oculars	Temporals	Total Length	Tail Divided by Total Length
U. S. N. M.													
"	24467	Pevely, Jefferson County, Missouri	J. Hurter........	male	17	125	35	6	6	0, 2	1 + 2	151	.173
"	27064	Waring, Kendall County, Texas...	R. T. Young.....	"	17	120	36	6	6	0, 2	1 + 2	242	.201
"	28412	Maxey, Tennessee..............	G. D. Morgan....	"	17	120	45	6	5	0, 3 0, 2	1 + 2	102	.206
"	31106	Austin, Texas..................	W. M. Wheeler...	"	17	121	37	6	6	0, 2	1 + 2	203	.192
"	37974	Olney, Illinois.................	R. Ridgway.....	"	17	124	43	6	6	0, 3	1 + 2	217	.198
"	37975	" ".................	"	"	17	123	40	6	6	0, 2	1 + 2	123	.184
"	38413	Bird Haven, near Olney, Illinois...	"	female	17	131	35		7	0, 2	1 + 2	233	.163
"	38414	" " " " "	"	"	(16–)17	127	36	6 6	6 6	1, 3 0, 1	1 + 2	163	.153
"	44254	Bay St. Louis, Mississippi........	C. S. Brimley....	"	17	122	31	6	6	0, 2	1 + 2	271	.153
"	49717	Bird Haven, Illinois............	R. Ridgway.....	"	17	126	31	6	6	0, 2	1 + 2	136	.140
"	52274	Kerrville, Texas...............	H. Candlin......	male	17	122	37	6	6	0, 2	1 + 2	224	.188
"	56217	St. Claire County, Illinois........	J. Hurter........	female	17	131	32	6	6	0, 2	1 + 2	316	.142
"	56218	St. Louis County, Missouri.......	"	male	17	119	39	6	6	1, 2 0, 2	1 + 2	211	.194
"	56219	" " " "	"	"	17	120	42	5 6	6	0, 2	1 + 2	99	.186
"	56220	Crawford County, "	"	"	17	123	41	6	6	0, 3 0, 2	1 + 2	253	.201
"	56221	" " "	"	female	17	130	33	6	5 6	0, 2	(1+1) +2	110	155
"	56222	Jefferson " "	"	male	17–19–17	124	39	6	6	0, 2	1 + 2	224	.190
"	56223	" " "	"	female	17	130	32	6	6	0, 2	1 + 2	268	.157
"	56224	" " "	"	male	17	122	38	6	6	0, 2	1 + 2	128	.178
"	56225	" " "	"	"	17	121	41	6	6	0, 2	1 + 2	155	.193
"	56226	" " "	"	female	17	130	35	6	6	0, 2	1 + 2	137	.160

Virginia valeriae valeriae (Baird and Girard)

1853. *Virginia valeriae*, Baird & Girard, Cat. N. Amer. Rept., pt. 1, p. 127 (type locality, Kent County, Maryland; type specimen, U. S. National Museum, no. 1962; Miss Valeria Blaney, collector). — Baird, Pac. R. R. Surv., vol. 10, pts. 3 & 4, Art. 1, 1859, pl. 33, fig. 94. — Jan, Archiv. Zoöl., Anat. Fisiol., vol. 2, fasc. 1, 1862, p. 24, fasc. 2, pl. 17, last fig.; Elen. sist. degli Ofidi, 1863, p. 34; Icon. Gen. Ophid., livr. 12, 1865, pl. 2, fig. 5. — Cope, Bull. U. S. Nat. Mus., no. 1, 1875, p. 35. — Jordan, Man. Vert., 1876, p. 182. — Smith, Geol. Surv. Ohio, vol. 4, 1882, p. 699. — Yarrow, Bull. U. S. Nat. Mus., no. 24, 1882, pp. 13, 83. — Davis & Rice, Bull. Illinois State Lab. Nat. Hist., 1883, p. 31; Bull. Chicago Acad. Sci., vol. 1, no. 3, 1883, p. 29. — Garman, S., Mem. Mus. Comp. Zoöl., vol. 8, no. 3, 1883, p. 98, pl. 7, fig. 3. — Yarrow, Smiths. Misc. Coll., no. 517, 1883, p. 13. — Cope, Proc. U. S. Nat. Mus., vol. 14, 1891, p. 599. — Garman, H., Bull. Illinois State Lab. Nat. Hist., vol. 3, art. 13, 1892, p. 307. — Hay, 17th Ann. Rep. Dept. Geol. Nat. Res. Indiana for 1891, 1892, pp. 488, 587. — Boulenger, Cat. Snakes Brit. Mus., vol. 2, 1894, p. 289. — Cope, Ann. Rep. U. S. Nat. Mus. for 1898, 1900, p. 1006, fig. 270. — Brown, Proc. Acad. Nat. Sci., Philadelphia, 1901, p. 83. — Brimley, Journ. Elisha Mitchell Sci. Soc., vol. 23, no. 4, 1907, p. 144. — Ditmars, Rept. Book, 1908, p. 272. — Brimley, Proc. Biol. Soc. Washington, vol. 23, 1910, p. 15. — Dunn, Copeia, no. 18, p. 6, no. 25, p. 63. — Miller, Copeia, no. 34, p. 68. — Stejneger & Barbour, Check List, 1917, p. 99. — Brimley, Journ. Elisha Mitchell Sci. Soc., vol. 34, no. 3, 1918, p. 147. — Dunn, Copeia, no. 53, 1918, p. 27.

1854. *Carphophis harperti*, Dumeril & Bibron, Erp. Gen., vol. 7, p. 135 (type locality, South Carolina; type specimen deposited in Paris Museum; collected by Harpert). *Virginia harpertii*, Dumeril and Bocourt (part), Miss. Sci. Mex. 1870, p. 543: pl. 32, figs. 3 to 3e (?). *Virginia harpertii*, Cope, Bull. U. S. Nat. Mus., no. 1, 1875, p. 35. — Garman, S., Mem. Mus. Comp. Zoöl., vol. 8, no. 3, 1883, p. 99.

Description. — Examination of twenty-six specimens and four published records shows the following scutellation: ventral plates, 111 to 130 (males, 111 to 122, average, 116; females, 115 to 130, average, 123); caudals, 22 to 40 (males, 32 to 40, average, 34; females, 22 to 32, average, 25); supralabials, 6; infralabials, 6, rarely 5 or 7; prefrontal and loreal forming anterior boundary of orbit; loreal long and narrow; postoculars usually 2, occasionally 1 or 3; temporals, 1 + 2, rarely 1 + 1; posterior chin shields generally longer than anterior, diverging;

scale rows 15 throughout, rarely traces of another row on either side; dorsal scales all smooth or weakly keeled posteriorly, particularly in region of vent, lowermost row distinctly wider than the rest.

Body in adults rather thick for its length, tapering gradually forwards to the snout, although often a little widened in the temporal region. Tail short, in males, .170 to .204, average, .184, of total length, and in females, .126 to .174, average, .133, tapering abruptly in females, more gradually in males. The largest specimen examined measured 275 mm., and came from Washington, D. C.

The general color above is dark brown or dark gray, either uniform or with numerous small black dots; beneath, whitish, unmarked. The small black dots, when present, tend to form four longitudinal rows, one on the first or second row of scales each side of the mid-dorsal row, and one about four scales down from the median row on each side, the lower rows tending to alternate with the upper. Each spot is separated by one or two scales, but the spots are less well defined and less regular than in *elegans*. A faint median dorsal light stripe may occasionally be distinguished. Belly, chin, lower labials, and lower part of the upper labials are immaculate and light, or the upper labials and part of the lower labials may be more or less suffused with the dorsal color. Along the middle of each dorsal scale a light longitudinal line is often discernible.

Range. — This form occurs from central New Jersey to southern Georgia and Alabama, north through central Tennessee, and probably into Kentucky (See Map III). It has not been reported from Florida.

In addition to the localities in the accompanying list of specimens, the following records appear to be reliable: Kent County, Maryland, and Anderson, South Carolina (Baird & Girard, 1853, pp. 127, 128); Mimsville, Baker County, Georgia (Brimley, 1910, p. 15); Nelson and Northampton Counties, Virginia (Dunn, 1918, p. 27).

H. Garman records Cook and Union counties, Illinois (1892, p. 308). These localities are held subject to verification for

the following reasons: Neither specimen was described nor is available for examination; Cook County is far north of any other records of this form; Union County is strictly within the range of *elegans*, and the specimen probably belonged to this form. Jan (1862, p. 24) records Savannah, Georgia, and although this has been plotted on the map, the specimen may perhaps have come from some miles inland. It is a record in need of verification.

Habitat and Habits. — On this subject Ditmars (1908, p. 273) says: "It feeds upon worms and the soft-bodied larvae of insects that burrow into decaying trees. A female captured in North Carolina on the 10th of August gave birth to seven young on the 15th of the same month. The tiny creatures were not as thick as an ordinary match."

Miller (1916, p. 68) reports finding "several individuals of this small snake on the trap ridges immediately north of Plainfield, New Jersey. . . . All were hiding under boards or stones in dry deciduous woods."

A specimen taken by Mr. R. W. Bennett at Washington, D. C., was kept for nearly a year by the writer. It fed on earthworms. It was found by Mr. Bennett near the Anacostia River "under a short chunk of log about a foot long and six inches thick." Mr. Bennett wrote at the time: "He is dull gray above, very light gray, almost white, beneath. The only markings are a double row of black spots down the back. (This specimen is now preserved and no spots can be seen.) . . . He is a gentle snake, but rather lively. When I first picked him up, he was almost flat, at least an inch broad and not over $\frac{3}{16}$ of an inch thick, perfectly flat below and slightly curved on the top surface. He soon assumed the round shape, and I have not seen him flat since." In captivity he generally remained out of sight.

Variation. — As was the case with *elegans*, the series of specimens now at hand is too small to show any geographic variation, except the tendency toward intergradation with *elegans* in the specimen from Tyree Springs, Tennessee. This is the only specimen having undivided caudals, and it has three.

Keels on the dorsal scales are fairly well developed in one male and in one female. In about half of the rest of each sex

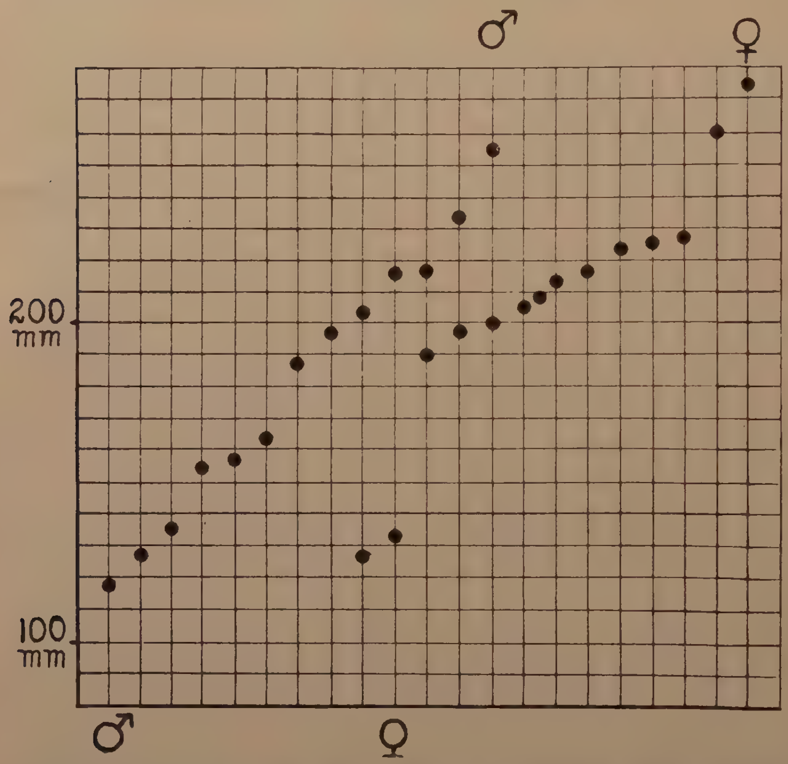


FIG. 15. Chart showing total length in millimeters of each complete specimen of *Virginia valeriae valeriae.*

keels are faintly discernible on the posterior portion of the body or tail, and in the remainder all the scales are smooth.

The total length in millimeters of each complete specimen examined is shown in the accompanying diagram (See Fig. 15).

List of Specimens of Virginia valeriae valeriae

Museum	Number	Locality	From Whom Received	Sex	Scale Rows	Ventrals	Caudals	Supralabials	Infralabials	Oculars	Temporals	Total Length	Tail Divided by Total Length
Ala......	......	Indian Creek, Tuscaloosa Co., Alabama...	H. H. Smith......	male	15	118	40	6	6	0, 2	1 + 2	135	.204
Amer.....	5187	Raleigh, North Carolina.............	C. S. Brimley.....	"	15	112	34	6	5 6	0, 1 0, 2	1 + 2	157	.191
"	18073	Watchung, New Jersey.............	R. Moldenke.....	"	15	113	34	6	6	0, 2	1 + 2	256	.176
Brit......	.....	Raleigh, North Carolina............	....	"	....	112	34						
"	.....	" " "	....	"	....	113	36						
"	.....	" " "	....	female	....	115	24						
Cornell...	4321	" " "	Brimley Brothers..	male	15	117	35	6	6	0, 2	1 + 2	202	.188
" ...	.....	Tallulah Falls, Georgia.............	J. C. Bradley.....	"	15	116	37	6	6	0, 2	1 + 2	236	.191
Field.....	2026	Raleigh, North Carolina.............	....	female	15	122	28	6	6	0, 2	1 + 2	127	.141
"	.....	" " "	C. S. Brimley.....	male	15	117	37	6	6	0, 3 0, 2	2 + 2 1 + 2	209	.201
M.C.Z....	122	Virginia........................	Dr. Jones........	"	15	118	34	..	..	0, 1 0, 2	1 + 2		
" ...	261	Roswell, Georgia..................	....	female	15	119	25	6	6	0, 2	1 + 2	205	.143
" ...	13059	Danville, Virginia.................	....	male	15	116	33	6	6	0, 2	1 + 2	197	.188
Mich.....	3777	Summerville, South Carolina...........	....	female	15	115	24	6	6	0, 1	1 + 2	212	.137
"	57710	District of Columbia................	R. W. Bennett....	"	15	121	25	6	6	0, 2	1 + 1 1 + 2	275	.127
Paris[1]...	.....	South Carolina....................	....	.....	15	111	32	6	6	0, 3	1 + 2		
U.S.N.M.	1876[2]	Anderson, South Carolina.............	....	.....	15	125	27						
"	1962[3]	Kent County, Maryland..............	....	.....	15	127	25						
"	2224	Tyree Springs, Tennessee.............	Prof. Owen.......	female	15[4]	121	25	6	6	0, 2	1 + 2	261	.138
"	6050	Southeastern United States............	....	"	17–15–17–15....17	117	32	6	6	0, 2	1 + 2	201	.174

LIST OF SPECIMENS OF VIRGINIA VALERIAE VALERIAE (Continued)

Museum	Number	LOCALITY	From Whom Received	Sex	Scale Rows	Ventrals	Caudals	Supralabials	Infralabials	Oculars	Temporals	Total Length	Tail Divided by Total Length
U.S.N.M.	7303	Cook County, Illinois	R. Kennicott	female	15	126	26	6	6	0, 2	1 + 2	226	.128
"	10742	Statesville, North Carolina	A. L. Barringer	"	15	119	22	6	6	0, 1	1 + 1 1 + 2	198	.126
"	11433	Near Washington, District of Columbia	G. Shoemaker	"	15	118	24	6	6	0, 3 0, 2	1 + 2	131	.137
"	13300	Alexandria County, Virginia	"	female	15	122	22	6	5 7 6	0, 1 0, 2	1 + 1	223	.126
"	17288	Great Falls, Maryland	C. W. Richmond	male	15	115	34	6	6	0, 2	1 + 2	128	.184
"	17289	Washington, District of Columbia	H. M. Smith	female	15	119	27	6	6	0, 2	1 + 2	215	.140
"	17446	Dunn-Loring, Virginia	G. D. Figgins	"	15	119	25	6	6	0, 3	1 + 2	191	.131
"	17639	Linden, Maryland	N. P. Scudder	male	15	115	32	6	6	0, 2	1 + 2	218	.174
"	36687	Woodside, Maryland	J. E. Benedict, Jr.	female	15	118	23	6	6	0, 3 0, 2	1 + 2	223	.132
"	52274	Washington, District of Columbia	E. H. Halback	male	15	115	34	6	7	0, 2	1 + 2	119	.181
"	52475	White Horse, Clarke County, Virginia	E. R. Dunn	female	15	130	29	6	6	0, 2	1 + 2		
"	56307	Raleigh, North Carolina	J. Hurter	male	15	116	32	6	6	0, 2	1 + 2	218	.170
"	62190	Rappahannock or Loudon County, Virginia	Mrs. W. B. Rowzie	"	15	114	33	7 6	6	0, 2	1 + 2	189	.180
"	62191	" " " " "	"	"	15	117	35	6	6	0, 2	1 + 2	154	.182
"	62192	" " " " "	"	"	15	119	32	6	6	0, 2 0, 3	1 + 2	162	.180

[1] Type of *Virginia harperti* Dumeril and Bocourt.
[2] Paratype of *Virginia valeriae* Baird and Girard.
[3] Type of *Virginia valeriac* Baird and Girard.
[4] Traces of 17 rows.

SUMMARY: RELATIONSHIPS BETWEEN ELEGANS AND VALERIAE

Examination of the foregoing descriptions can hardly fail to suggest that *valeriae* is a reduced form of *elegans*. In support of this point the following evidence is offered:

1. Examination of the accompanying table of averages will show that *valeriae* has fewer ventrals and fewer caudals, sex for sex, than *elegans*, and a proportionately shorter tail.

2. The largest specimen of the genus examined was an *elegans*, and of the latter form four females were larger than the largest female of *valeriae* and in both sexes there were more large individuals of *elegans* than of *valeriae* (Compare Figs. 14 and 15).

3. *Elegans* has 17 rows of scales throughout the body length, *valeriae* has 15. It has been shown by the writer in a previous study (1921, p. 10) that a low number of scale rows constant throughout the body length may be directly correlated with diminution in size accompanying the adoption of more secretive habits and this may well be the explanation of this type of formula in the genus Virginia. Especially significant then is the possession of the formula 17–19–17 by one otherwise typical example of *elegans*. If the argument above is correct *valeriae* is the more reduced and later form of the two.

4. The spasmodic and irregular development of keels on the dorsal scales of *elegans* is highly suggestive of degeneration in this feature, and their almost complete absence in *valeriae* may well be regarded as a later stage in their loss.

Other characters indicating that the genus as a whole is a degenerating one are: (1) variability of the postoculars in shape and number; (2) loss of preoculars and assumption of their function by extensions of the loreals and prefrontals; (3) tendency of the parietal and fifth upper labial plates to meet between the postoculars and the anterior temporal. The first of these features shows instability, often a characteristic of small aberrant snakes. The second and third matters are plainly correlated with a decrease in size of the head which forces rearrangements, and eliminations of the scutes. A dorso-

ventral flattening decreases the space between the parietals and the upper labials and the tendency to elimination of the anterior temporal is shown here by the frequent meeting of the parietal and fifth upper labial (See Fig. 12). Similarly, decrease in space in front of the eye has resulted in loss of the preoculars.

TABLE II

AVERAGES OF CERTAIN CHARACTERS OF THE TWO FORMS OF VIRGINIA

Character	Name and Sex							
	Male				Female			
	Elegans		*Valeriae*		*Elegans*		*Valeriae*	
	No. Specimens	Average	No. Specimens	Average	No. Specimens	Average	No. Specimens	Average
Ventral plates....	19	121	14	116	18	126	12	123
Caudal plates....	19	39	14	34	18	31	12	25
Total length divided by tail length........	19	.191	14	.184	17	.151	12	.133

All of these considerations make it clear to the writer that we are dealing here with a genus of snakes undergoing degenerative evolution towards underground life, and that the eastern form, *valeriae*, is the descendant of the western, *elegans*.

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OBSERVATIONS ON THE OVIPOSITING OF *TETRAOPES TETROPHTHALMUS* FORST*

WILLIAM J. CLENCH

The following observations on *Tetraopes tetrophthalmus* Forst. were made in the laboratory during July of 1921. A large wire cage, 2 x 2 x 4 ft., placed beside an open window was used in the experiment. The common milkweed, *Asclepias syriaca*, was used for the food plant; one half of the material consisted of strong vigorous plants, the other half of large but weakened plants, the latter exuding but little latex upon being cut or bruised.

Fifty pairs of Tetraopes, collected while copulating, during the first week of July, were placed in the cage. The insects began feeding at once upon the leaves and tips, and continued feeding during the entire time that the observations were being made. The third week after they were placed in the cage, the first eggs were deposited, the females accepting in all cases the less vigorous plants for ovipositing. A restlessness was first noticed in one individual. Walking up and down several plants, the insect finally came to rest half-way up the stem of one plant. In this position it remained motionless for several minutes, and then cut into the plant stem with its mandibles a horizontal slit one eighth of an inch in length. This continued until a small hole had been made into the hollow portion of the stem.

After this operation the female turned in the opposite direction, facing downwards, and oviposited into the hole she had

* Contributions from the Entomological Laboratory of the Bussey Institution, Harvard University; No. 224.

just made. This was repeated several times by the same female, the number of eggs varying from three to ten each time. Other females soon oviposited in the same manner, using all portions of the stem, but preferring in most cases the middle part.

When the stem was split, the eggs were found adhering to one another and clustered about the opening produced by the female. They were yellowish in color, elongate, and slightly tapering at one end. Length, 1.75 mm.; width, 0.4 mm. The yellowish coloration is due to the young larvae, the shells being creamy-white after hatching. The young larvae, upon emerging, were covered with a heavy pubescence, but both color and amount of pubescence change as the larvae grow. Full-grown larvae found the previous fall were a dull white, and exhibited only a small amount of pubescence along the sides of each segment and on the posterior end.

Observations to determine the method by which the larvae reach the roots, where the full-grown larvae are to be found, were impossible at the time these studies were made. F. C. Craighead stated in a letter to me that he believed the larvae made their way down to the roots through the hollow portions of the stem, eating their way through the internodes.

The abundance of the latex in healthy strong plants might account for the female's seeking the less vigorous plants for ovipositing. Extensive feeding of the adults on the leaves and stems causes a large amount of latex to exude from the feeding punctures. The feeding of the previous year's larvae in the roots brings about a premature yellowing of the leaves, resulting in a reduced vigor of the plants. This was noticed in the field during the time of the laboratory observations, but an examination of the weakened plants, under natural conditions, yielded no eggs.

University of Michigan

THE LAND VERTEBRATE COMMUNITIES OF WESTERN LEELANAU COUNTY, MICHIGAN, WITH AN ANNOTATED LIST OF THE MAMMALS OF THE COUNTY

ROBERT TORRENS HATT

INTRODUCTION

The following paper is written from material gathered in Western Leelanau County, Michigan, from July 9 to September 15, 1921, from a number of observations made during the summer months of 1916, 1917, and 1918, from information supplied by several residents of the county, and from a few previously published records. During 1921, Leland was made the base of work. From August 17 to August 28, camp was established on Good Harbor Bay at the mouth of Traverse Creek. A trip was made to North Manitou Island in 1918.

The region between Sleeping Bear Point and Gill's Pier was rather thoroughly covered on foot, while other parts of the county were surveyed from automobile.

As intensive field work was carried on only in the western part of the county lying between Pyramid Point and Gill's Pier, and east of the shore-line from one to five miles, the analysis of the habitats is limited to this area, although it is probable that the descriptions would apply fairly well over the whole county.

It has been attempted to make the lists of the mammals complete. The birds listed are those seen or collected. All the reptiles and amphibians found were noted and usually collected. For a few of the habitats the lists of plants approach completeness from the standpoint of the typical places studied, but in most cases it was not convenient to collect and identify all the plants found, and only general statements can be made. The

specimens collected are deposited in the Museum of Zoölogy, University of Michigan.

ACKNOWLEDGMENTS

The author is responsible for the identification of the mammals and birds mentioned in this paper, while he is indebted to Mrs. Helen T. Gaige, of the Museum of Zoölogy, for the identifications of the reptiles and amphibians, and to Mrs. Charles A. Woodcock, of Louisville, Kentucky, for the plants. The author also wishes to express his gratitude to L. R. Dice, of the Museum of Zoölogy, for his constant advice in all matters connected with the preparation of this paper, to Dr. W. Kendrick Hatt for supporting the work, and to the many friends who furnished aid from time to time in the field, and supplied information concerning the mammals of the county.

TOPOGRAPHY

Leelanau County is a part of the Southern Peninsula of Michigan and roughly has the form of a triangle, bounded on the west by Lake Michigan, and on the east by Traverse Bay, while Grand Traverse and Benzie counties lie to the south. Also included in the county are South and North Manitou islands, and South and North Fox islands, lying to the west and north in Lake Michigan. One other small island, Bellow Island, lies in Northport Bay.

The county is twenty miles wide at its base, while from the county line to the northernmost point of the mainland, it is thirty miles long. The mainland has an area of two hundred and thirty-two square miles, twenty-three square miles of which are occupied by thirty-two lakes. The largest of these lakes is Lake Leelanau (See Plate XXIV, Fig. 1), with an area of ten square miles, while Glen Lake, with an area of seven square miles, is second in size. In all of these lakes the shore line is fairly regular and typical of a mature development. The lake basins are glacial in origin. The larger lakes all have a visible outlet, but the greater number in the county have no surface

outlet. There are only three large streams, but there are many small streams that flow the entire year.

The greater portion of the Lake Michigan shore is bordered by sandy lake-bed deposits, often drifted into dunes, but usually covered with a light timber growth. Occurring as breaks in these deposits are land-laid moraines, which in such places as Pyramid Point and the shore north of Leland (See Plate XXV, Fig. 1) have been exposed to constant wave action, and steep clay bluffs have been formed. The greater portion of the interior of the county is composed of such moraines and typified by a lightly dissected, rolling topography. Along the borders of Lake Leelanau occur some sandy lake-bed deposits. In the northwest part of the peninsula there is a strip of boulder-clay plains on which are a number of drumlins with a northwest, southeast trend.[1]

This area supports little timber and is extensively used for agriculture. In the southeastern and south-central part of the county is an extensive outwash plain which contains a large number of very small lakes, but no large ones. South Manitou Island is largely a land-laid moraine with a few drifting sand-dunes towards the higher western edge. North Manitou Island, the largest of the islands of the county, contains fifteen square miles. Its northern portion is composed of land-laid moraines, while its southern portion is largely sandy drift and lake-laid deposits, with many large shifting dunes. The Fox Islands are predominantly lake-bed deposits, with a few drifting dunes, but with most of the surface covered with a hardwood forest.

HISTORY

There was formerly a rather large Indian population in this county and abundant evidence of their occupancy remains. The region was probably inhabited in turn by the Chippewas, Hurons, and Ottawas.[2] The region was unknown to white men,

[1] Leverett, Frank. *Map of the Surface Formations of the Southern Peninsula of Michigan. Geological Survey of Michigan,* Lansing, 1911.

[2] Littell, Joseph. *Leland,* pp. 1–61. Indianapolis Printing Co., 1920. Privately published.

with the probable exception of a few trappers, until 1848, when the first white settler arrived at Sleeping Bear Bay. Some other settlers arrived in the next few years, and a dam was constructed across the stream at the present site of Leland. This impounded the waters of the three lakes which drained into this stream, and formed one long lake which is now known as Lake Leelanau. From the years 1860 to 1890, lumber operations were in full sway and the greater part of the original forest cover was removed. As this industry died many of the flourishing villages were deserted, and the occupants either moved to other regions or devoted their time to agriculture or commercial fishing. About 1900, summer resorters were attracted to the region and since that time summer cottages have increased in number to such an extent that the shore habitats have become increasingly altered. The Indians have all but disappeared. The major portion of the county is now cleared, but not extensively developed agriculturally. The only considerable cover of virgin timber left is in the vicinity of Glen Lake.

HABITATS

The habitats were not studied with equal completeness; neither are they of equal extent or importance, and perhaps in many places could well be subdivided further than I attempt. Further investigation would doubtless reveal other communities than those here recognized, but it is the author's belief that the major habitats are as here described. These, so far as the vertebrates are concerned, certainly would not be quite the same on the islands.

During 1921 there was so little rainfall that the shores were wider than in most years, and the relation between the vegetation and the water's edge was in general quite unusual.

The habitats recognized may be listed as follows:

Exposed Shore:	Protected Shore:
Open water	Submerged vegetation
Beach	Floating vegetation
Clay bluff	Mud-flat
Moving dune	Cattail
Forested lake-border	Herbaceous lake-border
	Willow thicket

Stream Conditions:

Aquatic
Cut bank
Herbaceous stream-border
Forested stream-border

Meadow:

Meadow

Swamp:

Cedar swamp

Bog:

Leather-leaf bog

Forest:

Dry deciduous forest
Wet deciduous forest
Conifer forest

Air:

Aerial

Burn and Clearing:

Grass field
Sumach
Overgrown clearing

Artificial Conditions:

Cultivated field
Orchard
Edificarian

The habitats will be described in the order in which they are listed.

EXPOSED SHORE

Open water habitat:

Podilymbus podiceps. Pied-billed grebe. Occasional.
Gavia immer. Loon. Rare.
Larus argentatus. Herring gull. Common.
Mergus americanus. Goosander. Seasonally common.
Branta canadensis canadensis. Canada goose. Rare.
Ursus americanus americanus. Black bear. Rare.
Ondatra zibethica zibethica. Muskrat. Rare.

This habitat includes the waters off exposed shores in places where wave action keeps the bottom free of rooted vegetation. The bottom varies in texture from a fine sand to large boulders. Where rocks afford protection, crawfishes and other invertebrates are often numerous.

This habitat occurs in Lake Michigan and the greater portions of the shore lines of Lake Leelanau and Glen Lake, while such areas occur in small patches in most of the other lakes.

No mammals were collected, but in Lake Leelanau muskrats have been seen in this habitat and a bear has been taken at Glen Lake. Muskrats are conspicuoulsy absent in the northern

part of Lake Leelanau, where this habitat prevails, but are abundant near the narrows at Provemont, where extensive rooted vegetation occurs.

Beach habitat:

Bufo fowleri. Toad. Numerous at night.
Rana cantabrigensis. Wood frog. Occasional.
Chrysemys marginata marginata. Painted turtle. Rare.
Larus argentatus. Herring gull. Numerous.
Sterna hirundo. Common tern. Occasional.
Pisobia minutilla. Least sandpiper. Rare.
Actitis macularia. Spotted sandpiper. Common.
Oxyechus vociferus. Killdeer. Common.
Corvus brachyrhynchos brachyrhynchos. Crow. Abundant.
Quiscalus quiscula aeneus. Bronzed grackle. Occasional.
Melospiza melodia melodia. Song sparrow. Common.
Vulpes fulva. Red fox. Tracks. Rare.
Procyon lotor lotor. Raccoon. Tracks. Occasional.
Mustela noveboracensis noveboracensis. New York weasel. Numerous.
Mustela vison mink. Mink. Occasional.
Mephitis mephitis nigra. Skunk. Common.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Common.
Sciurus niger rufiventer. Fox squirrel. Rare.
Sciurus carolinensis leucotis. Gray squirrel. Rare.
Glaucomys sabrinus macrotis. Canada flying squirrel. Rare.
Sylvilagus floridanus mearnsii. Cottontail. Common at night.

This habitat varies from a few feet to three hundred feet in width. The ground varies from a fine sand to a coarse gravel. Often the Lake Michigan beach is distinctly divided into three belts, but these are not sufficiently distinct as to vertebrate fauna to be recognized as separate habitats. These belts are: (1) a strip of barren beach; (2) an area of driftwood; and, (3) where the beach is preëminently sandy, an area of beach-grass (*Ammophila arenaria*). In the wider areas, other plants occasionally occur in greater or less abundance, notably the beach-pea (*Lathyrus maritimus*), and poison-ivy (*Rhus toxicodendron*). During heavy storms small lagoons often form and persist for a few days. There are a few semi-permanent lagoons too, but these are too small to be of importance.

The open beach extends in a practically continuous strip along the shore of Lake Michigan, between the water's edge and the clay bluffs, the forest, or the sand-dunes. Along the smaller

lakes this habitat is poorly developed, and has little or no vegetation growing on it.

Clay-bluff habitat:

Bufo fowleri. Toad. Common.
Thamnophis sirtalis sirtalis. Garter snake. Numerous.
Haliaeetus leucocephalus leucocephalus. Bald eagle. Rare.
Ceryle alcyon. Kingfisher. Common.
Tyrannus tyrannus. Kingbird. Common.
Sayornis phoebe. Phoebe. Numerous.
Cyanocitta cristata cristata. Blue jay. Occasional.
Corvus brachyrhynchos brachyrhynchos. Crow. Abundant.
Molothrus ater ater. Cowbird. Common.
Agelaius phoeniceus phoeniceus. Red-winged blackbird. Numerous.
Astragalinus tristis tristis. Goldfinch. Numerous.
Spizella passerina passerina. Chipping sparrow. Common.
Melospiza melodia melodia. Song sparrow. Abundant.
Melospiza georgiana. Swamp sparrow. Occasional.
Riparia riparia. Bank swallow. Large nesting colonies.
Dumatella carolinensis. Catbird. Occasional.
Penthestes atricapillus atricapillus. Black-capped chickadee. Common.
Planesticus migratorius migratorius. Robin. Common.
Vulpes fulva. Red fox. Rare.
Mustela noveboracensis noveboracensis. New York weasel. Numerous.
Mephitis mephitis nigra. Skunk. Occasional.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Occasional.
Marmota monax rufescens. Woodchuck. Occasional.
Sciurus hudsonicus loquax. Red squirrel. Occasional.

The clay bluffs are found only along Lake Michigan and attain their maximum development just north of Leland. They range from sixty to one hundred and twenty-five feet in height. Steep exposed slopes below sixty feet in height are generally forested and therefore are not included in this habitat. The soil is a sandy clay, containing large boulders, and, locally, heavy gravel deposits. Near the top of the bluffs the soil is comparatively dry, but near the base it is well saturated and small landslides are frequent.

The lower border is bounded by the beach and the upper by a narrow belt of trees or an open field. The upper third of this habitat is usually a steep barren clay bank, often with a vertical drop of ten feet or more. Here are many bank swallow nests and some fox holes. Below this, many herbaceous plants take root, such as the horsetail rush (*Equisetum hyemale*), red

clover (*Trifolium pratense*), sow thistle (*Sonchus arvensis*), goldenrod (*Solidago canadensis*), and some grasses. Further down, the woody plants have a foothold. The most abundant of these are the poison ivy (*Rhus toxicodendron*), leather-leaf (*Chamaedaphne calyculata*), quaking aspen (*Populus tremuloides*), pin cherry (*Prunus pennsylvanica*), paper birch (*Betula alba papyrifera*), and arbor-vitae (*Thuja occidentalis*).

Moving-dune habitat:

This habitat is of barren moving sand. Occasionally along the sides there is a fringing growth of beach grass (*Ammophila*). No collecting was done on these dunes, but certainly no vertebrates make their homes here. There were numerous tracks crossing the dunes, however, and those of fox, rabbits, and mice were identified.

The only moving sand-dunes that occur in well-developed form in the area studied, are on Pyramid Point.

Forested lake-shore habitat:

Procyon lotor lotor. Raccoon. Reported.
Mustela noveboracensis noveboracensis. New York weasel. Common.
Mustela vison mink. Mink. Reported.
Mephitis mephitis nigra. Skunk. Numerous.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Common.
Erethizon dorsatum dorsatum. Porcupine. Signs.
Tamias striatus lysteri. Chipmunk. Occasional.
Sciurus carolinensis leucotis. Gray squirrel. Occasional.
Sciurus hudsonicus loquax. Red squirrel. Common.
Glaucomys sabrinus macrotis. Flying squirrel. Occasional.
Sylvilagus floridanus mearnsii. Cottontail. Occasional.

In character this habitat is little different except for the presence of water from the other forest habitats described later, but its fauna is somewhat different. It may be defined as a strip of forest adjacent to an exposed shore, used by certain vertebrates which do not penetrate far into the forest. No special collecting was done in this habitat, so only specimens secured at random or reported are listed.

This habitat occurs extensively along lakes Michigan and Leelanau, and to a lesser degree on the smaller lakes.

PROTECTED SHORE

Submerged-vegetation habitat:

Necturus maculosus. Mud-puppy. Reported.
Rana pipiens. Leopard frog. Abundant.
Rana clamitans. Green frog. Common.
Natrix sipedon. Water snake. Occasional.
Chelydra serpentina. Snapping turtle. Occasional.
Chrysemys marginata marginata. Painted turtle. Common.
Podilymbus podiceps. Pied-billed grebe. Common.
Gavia immer. Loon. Occasional.
Sterna hirundo. Common tern. Occasional.
Anas rubripes. Black duck. Occasional.
Marila americana. Redhead. Occasional.
Ceryle alcyon. Kingfisher. Common.
Ondatra zibethica zibethica. Muskrat. Common.

This habitat is characterized by the growth of Potomogeton, Chara, and other submerged plants. Food in the form of fishes and insects is abundant here. Animals other than those listed certainly pass over the frozen surface in winter.

Areas of this sort occur in Lake Leelanau and cover the major portion of the smaller lakes. In Lost Pond this habitat includes all the Lake.

Floating-vegetation habitat:

Rana pipiens. Leopard frog. Abundant.
Rana clamitans. Green frog. Common.
Chelydra serpentina. Snapping turtle. Occasional.
Chrysemys marginata marginata. Painted turtle. Abundant.
Podilymbus podiceps. Pied-billed grebe. Common.
Botaurus lentiginosus. Bittern. Occasional.
Ardea herodias herodias. Great-blue heron. Occasional.
Helodromas solitarius solitarius. Solitary sandpiper. Lingering migrant.
Actitis macularia. Spotted sandpiper. Abundant.
Oxyechus vociferus. Killdeer. Common.
Quiscalus quiscula aeneus. Bronzed grackle. Numerous.
Condylura cristata. Star-nosed mole. Rare.
Ondatra zibethica zibethica. Muskrat. Abundant.

The white and yellow water-lilies (*Castalia odorata* and *Nymphaea advena*) are distinctive of this habitat in most places. The presence in other lakes, notably in Duck Lake, of large floating rafts of duckweeds (*Lemna sp.*), pondweed (*Potamogeton*

sp.), *Chara sp.*, and other plants, is characteristic. Large numbers of wading birds feed on these rafts.

This habitat is extensive in the small lakes and the narrower parts of Lake Leelanau.

Mud-flat habitat:

Rana pipiens. Leopard frog. Abundant.
Rana clamitans. Green frog. Abundant.
Helodromas solitarius solitarius. Solitary sandpiper. Common in August.
Actitis macularia. Spotted sandpiper. Abundant.
Oxyechus vociferus. Killdeer. Abundant.
Corvus brachyrhyncos brachyrhyncos. Crow. Common.
Condylura cristata. Star-nosed mole. Rare.
Blarina brevicauda talpoides. Short-tailed shrew. Rare.
Procyon lotor lotor. Raccoon. Tracks abundant.
Mustela noveboracensis noveboracensis. New York weasel. Numerous.
Mustela vison mink. Mink. Tracks occasional.
Mephitis mephitis nigra. Skunk. Common.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Rare.
Ondatra zibethica zibethica. Muskrat. Common.
Sylvilagus floridanus mearnsii. Cottontail. Occasional.

In ordinary years mud-flats are practically non-existent, while in a season of drought, such as that of 1921, this habitat is well developed around many of the small lakes. In 1921 it varied in width from two or three feet to fifty feet. Its soil aspects differ on different lakes. Along Lake Leelanau it is a light silt, heavily mixed with sand. At Duck Lake it is of a very mucky character, and in places is totally composed of organic ooze. The Loon Lake flats are of heavy marl. Nearest the water's edge the flat is usually barren. Farther back, plants grow. Among the species in greatest abundance are: *Scirpus cyperinus*, *Calamagrostis inexpansa*, *Equisetum hyemale*, and *Equisetum arvense.*

Wading birds are numerous in this habitat, but few could be identified. At Duck Lake the star-nosed mole seems to prefer this situation for its burrows, the carnivores for a highway, while muskrats crossed it to obtain food.

Cattail habitat:

Rana pipiens. Leopard frog. Numerous.
Rana clamitans. Green frog. Occasional.

Rallus virginianus. Virginia rail. Occasional.
Agelaius phoeniceus phoeniceus. Red-winged blackbird. Numerous.
Vermivora rubricapilla rubricapilla. Nashville warbler. Rare.
Procyon lotor lotor. Raccoon. Tracks occasional.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Occasional.
Ondatra zibethica zibethica. Muskrat. Numerous.

In this habitat the dominant plant, *Typha latifolia,* grows so densely that almost all others are excluded. Part grows on ground that is covered by water, but the major part is on moist earth. The height and density of the growth make food, light, and travel conditions greatly different from the mud-flat habitat. In places it is so dense that the larger animals go around it rather than through it.

This habitat occurs locally on most of the lakes of the county and is dominant on a few.

Herbaceous lake-border habitat:

Rana pipiens. Leopard frog. Common.
Rana clamitans. Green frog. Occasional.
Thamnophis sirtalis sirtalis. Garter snake. Common.
Sistrurus catentatus catentatus. Rattlesnake. Reported.
Archilochus colubris. Ruby-throated hummingbird. Occasional.
Agelaius phoeniceus phoeniceus. Red-winged blackbird. Occasional.
Astragalinus tristis tristis. Goldfinch. Numerous.
Melospiza melodia melodia. Song sparrow. Abundant.
Blarina brevicauda talpoides. Short-tailed shrew. Occasional.
Mustela noveboracensis noveboracensis. New York weasel. Occasional.
Mephitis mephitis nigra. Skunk. Occasional.
Peromyscus leucopus noveboracensis. Northern deer-nouse. Abundant.
Microtis pennsylvanicus pennsylvanicus. Meadow vole. Numerous.
Sylvilagus floridanus mearnsii. Cottontail. Occasional.

Protected areas often have a considerable herbaceous growth of a type notably different from those hitherto described. This community varies in different places in accord with the soil conditions, available moisture, light, and other factors, but the difference in vertebrate fauna is not strongly enough marked to justify subdivision. Marsh grasses, mints, jewel-weed, cardinal flower, and plantains are typical of this habitat. A list of those plant species which were found most commonly in an area studied along the southern shore of Duck Lake is representative, and is given on the following page:

Ranunculus hispidus. Buttercup.
Trifolium pratense. Red clover.
Trifolium repens. White clover.
Impatiens noli-tangere. Jewel-weed.
Nepeta cataria. Catnip
Lycopus Europaeus. Water horehound.
Mentha arvensis Lanata. Mint.
Plantago major. Common plantain.
Plantago lanceolata. Ripple-grass.
Lobilia cardinalis. Cardinal flower.
Eupatorium purpureum maculatum. Joe-pye weed.
Eupatorium perfoliatum. Bonset.
Solidago erecta. Goldenrod.
Solidago tenuifolia. Goldenrod.

In places this habitat has a network of runways in it, largely the work of the meadow-voles. It varies in width from two or three feet to two hundred feet.

Willow-thicket habitat:

Rana pipiens. Leopard frog. Rare.
Dryobates pubescens medianus. Downy woodpecker. Occasional.
Astragalinus tristis tristis. Goldfinch. Numerous.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Common.
Sylvilagus floridanus mearnsii. Cottontail. Occasional.

Back from the herbaceous area of the lake border there is often a willow thicket at the forest edge. Only one species of willow was found growing in such groups, the black willow (*Salix nigra*), and but rarely were the seedlings of other trees seen in these clumps. Often however, there is an undergrowth of herbaceous plants of species similar to those mentioned in the herbaceous lake-border habitat, but in less abundance. Although traps were kept in this habitat for several days, but a few specimens of deer-mice were taken.

STREAM CONDITIONS

Aquatic habitat:

Rana pipiens. Leopard frog.
Natrix sipedon sipedon. Water snake.
Chelydra serpentina. Snapping turtle.
Chrysemys marginata marginata. Painted turtle.
Lutra canadensis canadensis. Otter. Reported.
Ondatra zibethica zibethica. Muskrat.

The streams of the region support little aquatic vegetation; what little there is, is confined to the borders. Some of the streams are quite sluggish, but in most of them there is a fairly rapid flow. The bottoms are usually sandy or gravelly. On stream borders the following plants were identified: arrowhead (*Sagittaria latifolia hastata* and *S. heterophylla*), white water lily (*Castalia odorata*), water-plantain (*Alisma Plantago-aquatica*), water arum (*Calla palustris*), and many grasses and sedges.

Cut-bank habitat:

Bufo fowleri. Toad. Occasional.
Rana pipiens. Leopard frog. Occasional.
Chelydra serpentina. Snapping turtle. Eggs found.
Mustela vison mink. Mink. Tracks numerous.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Rare.
Sylvilagus floridanus mearnsii. Cottontail. Occasional.

Along some of the streams are found cut banks of sufficient size to be recognized as a distinct habitat. The bank is usually sandy. This habitat is barren of plant life and differs from the other stream habitats mostly in negative characters. Trapping here brought few specimens.

Herbaceous stream-border habitat:

Rana pipiens. Leopard frog. Abundant.
Chrysemys marginata marginata. Painted turtle. Common.
Rallus virginianus. Virginia rail. Numerous.
Porzana carolina. Sora rail. Occasional.
Actitis macularia. Spotted sandpiper. Occasional.
Sayornis phoebe. Phoebe. Numerous.
Molothrus ater ater. Cowbird. Common.
Astragalinus tristis tristis. Goldfinch. Common.
Pooecetes gramineus gramineus. Vesper sparrow. Common.
Spizella passerina passerina. Chipping sparrow. Abundant.
Melospiza melodia melodia. Song sparrow. Abundant.
Vireosylva olivacea. Red-eyed vireo. Numerous.
Planesticus migratorius migratorius. Robin. Abundant.
Sialia sialis sialis. Bluebird. Occasional.
Mephitis mephitis nigra. Skunk. Occasional.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Abundant.
Synaptomys cooperi. Lemming vole. Rare.
Microtis pennsylvanicus pennsylvanicus. Meadow vole. Occasional.
Ondatra zibethica zibethica. Muskrat. Occasional.

This habitat varies greatly in character and in most places is preëminently artificial. The area which I studied is not disturbed by grazing, and conditions are at least approximately primitive. Collecting was done along Traverse Creek.

Where the banks are low the stream is ordinarily fringed by a belt of sedges. Immediately back of these occurs a rank growth of grasses, mints, jewel-weed, nettles, berry bushes, and other plants. Commonly the growth is four or more feet high. The habitat is considered as extending back from the stream's edge about twenty-five feet where the conditions are the same for a greater distance from the stream.

Forested stream-border habitat:

No collecting was done in this habitat and consequently little is known of its fauna. Where the streams are bordered with forests, the trees are all of small size, as these areas were cleared when the district was lumbered. The usual trees are hemlock, arbor-vitae, black birch, and sugar-maple.

MEADOW

Meadow habitat:

Meadow conditions occur only in a few limited areas and there was no opportunity to study these.

SWAMP

Cedar-swamp habitat:

Rana pipiens. Leopard frog. Abundant.
Rana cantabrigensis. Wood frog. Common.
Dryobates villosus villosus. Hairy woodpecker. Rare.
Dryobates pubescens medianus. Downy woodpecker. Numerous.
Oporornis philadelphia. Mourning warbler. Occasional.
Penthestes atricapillus atricapillus. Black-capped chickadee. Abundant.
Mustela noveboracensis noveboracensis. New York weasel. Tracks abundant.
Mustela vison mink. Mink. Tracks common.
Mephitis mephitis nigra. Skunk. Occasional.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Common.
Synaptomys cooperi. Lemming vole. Rare.
Evotomys gapperi gapperi. Red-backed mouse. Abundant.
Microtis pennsylvanicus pennsylvanicus. Meadow mouse. Occasional.

Sciurus hudsonicus loquax. Red squirrel. Rare.
Lepus americanus americanus. Snowshoe hare. Reported abundant.

The growth in this habitat is very dense and travel through the swamps quite difficult. Often there is a great deal of stagnant water, while in the swamps at the ends of Lake Leelanau there are small streams. The white cedar (*Thuja occidentalis*) is dominant, while a few tamarack (*Larix laricina*), willow (*Salix sp.*), canoe birch (*Betula alba papyrifera*), and ash compose the major part of the tree covering. Few of the trees attain a diameter of more than one foot. The soil is deep, rich, and moist. The ground is either barren or covered with mosses, liverworts, and grasses. Many logs, mostly well along in decay, directly on the ground, suspended above it, or lying across the stream, furnish highways and shelter for the mammals, and homes for many invertebrates. Black ants are so numerous that most of the small mammals trapped were badly damaged by them before they could be collected. Mosquitoes are very abundant in the summer months. The streams contain many small fishes, and thus mink are attracted along them. The streams have a dense growth of a species of arrowhead (*Sagittaria sp.*) and water arum (*Calla palustris*).

Cedar swamps occur in low lands throughout the county, notably along the shores of Lake Leelanau.

BOG

Leather-leaf bog habitat:

Circus hudsonius. Marsh hawk. Occasional.
Tyrannus tyrannus. Kingbird. Numerous.
Molothrus ater ater. Cowbird. Common.
Agelaius phoeniceus phoeniceus. Red-winged blackbird. Numerous.
Melospiza melodia melodia. Song sparrow. Abundant.
Dumatella carolinensis. Catbird. Occasional.
Troglodytes aedon aedon. House wren. Occasional.
Blarina brevicauda talpoides. Short-tailed shrew. Rare.
Mephitis mephitis nigra. Skunk. Common.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Common.
Sciurus hudsonicus loquax. Red squirrel. Rare.

The only bog conditions found were in a depression north of Leland, bordered on the one hand by a dry field and on the

other by a dense forest. The dominant plant is the leather-leaf (*Chamaedaphne calyculata*), while the bog reed-grass (*Calamagrostis confinis*), wool-grass (*Scirpus cyperinus*), and cattail (*Typha latifolia*) are unevenly dispersed through the habitat. Sphagnum covers the bases of the bushes and in ordinary years some forms of algae grow in the stagnant water, which then stands over the ground. In 1921 because of the drought there was no standing water whatsoever, and probably the fauna is usually quite different from that recorded in this year. Several species of beetles, grasshoppers, and katydids are abundant in this habitat.

FOREST

Dry deciduous-forest habitat:

Bonasa umbellus umbellus. Ruffed grouse. Common.
Dryobates pubescens medianus. Downy woodpecker. Common.
Colaptes auratus luteus. Flicker. Numerous.
Antrostomus vociferus vociferus. Whippoorwill. Occasional.
Myiochanes virens. Wood pewee. Common.
Cyanocitta cristata cristata. Blue jay. Common.
Corvus brachyrhynchos brachyrhynchos. Crow. Abundant.
Spizella passerina passerina. Chipping sparrow. Common.
Pipilo erythropthalmus erythropthalmus. Chewink. Common.
Piranga erythromelas. Scarlet tanager. Rare.
Setophaga ruticilla. Redstart. Occasional.
Sitta carolinensis carolinensis. White-breasted nuthatch. Common.
Sitta canadensis. Red-breasted nuthatch. Rare.
Penthestes atricapillus atricapillus. Black-capped chickadee. Abundant.
Planesticus migratorius migratorius. Robin. Abundant.
Procyon lotor lotor. Raccoon. Reported.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Abundant.
Tamias striatus lysteri. Chipmunk. Common.
Sciurus hudsonicus loquax. Red squirrel. Abundant.
Sciurus carolinensis leucotis. Gray squirrel. Common.
Sciurus niger rufiventer. Fox squirrel. Numerous.
Glaucomys sabrinus macrotis. Flying squirrel. Reported.

The dry deciduous forests are extensive. They are composed largely of mature beech, oaks, and maples. The forest crown is high and dense. Undergrowth is scanty and consists mainly of seedlings of these same species of trees. The forest floor is thickly carpeted with leaves and mosses. In this type

of forest are found fox squirrels, chipmunks, and raccoons, whereas in the damp deciduous forests these are either not so abundant, or totally absent. The factors controlling distribution between these two types of forests are not known, although it seems possible that the greater abundance of acorns here might be a deciding factor in the case of the fox squirrels and chipmunks, and the greater number of hollow trees a factor that would favor the raccoons. The red squirrels, which seem to thrive on the pine seeds would not be expected to respond so closely to the influence of acorn abundance.

Wet deciduous-forest habitat:

Plethodon cinereus. Red backed salamander. Abundant in rotten logs.
Hyla crucifer. Spring peeper. In rotten stump. Rare.
Bonasa umbellus umbellus. Ruffed grouse. Common.
Dryobates pubescens medianus. Downy woodpecker. Occasional.
Myiochanes virens. Wood pewee. Common.
Cyanocitta cristata cristata. Blue jay. Numerous.
Seiurus aurocapillus. Oven bird. Numerous.
Sitta carolinensis carolinensis. White-breasted nuthatch. Occasional.
Sitta canadensis. Red-breasted nuthatch. Rare.
Penthestes atricapillus atricapillus. Black-capped chickadee. Common.
Planesticus migratorius migratorius. Robin. Common.
Blarina brevicauda talpoides. Short-tailed shrew. Abundant.
Vulpes fulva. Red fox. Reported.
Mephitis mephitis nigra. Skunk. Occasional.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Abundant.
Erethizon dorsatum dorsatum. Porcupine. Reported.
Tamias striatus lysteri. Chipmunk. Occasional.
Sciurus hudsonicus loquax. Red squirrel. Common.
Glaucomys sabrinus macrotis. Flying squirrel. Reported.
Sylvilagus floridanus mearnsii. Cottontail. Occasional.

Mature trees occur in the low areas and near the lakes, sometimes forming a dense canopy overhead. Usually, however, the younger trees form the mass of the forest and shut off the light so effectively as generally to exclude green plants from the forest floor. Indian pipes (*Monotropa uniflora*), coral fungi, and toadstools, are often found in these situations. In a few places, large ferns and bearberry grow luxuriantly. Fewer sugar-maple and yellow birch, but more linden grow here than in the dry deciduous forests. Hemlocks and pines occur, but are few in number. Well rotted logs are more numerous and furnish

suitable homes for some of the amphibians. In one locality trapped, the bob-tailed shrews were the most numerous mammal found; the ground carpet was an intricate network of their burrows, but the condition seemed to be quite local, for in areas apparently physically like this, no shrews were found.

Conifer-forest habitat:

Vulpes fulva. Red fox. Reported.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Common.
Erethizon dorsatum dorsatum. Porcupine. Reported.
Sciurus hudsonicus loquax. Red squirrel. Common.

There is little forest left that is predominantly composed of conifers, but such areas do occur and seem to differ in faunal association from the forest types hitherto described. Pines, hemlocks, and balsam fir are the most abundant of the conifers, while beech, maple, birch, and linden are sparsely scattered throughout. The forest floor is composed of a heavy mat of needles, usually underlaid by sand, or sometimes covered with a low growth of mosses, wintergreen, and a few seedlings. There is little underbrush and the trees generally grow closely together.

AIR

Aerial habitat:

Myotis lucifugus lucifugus. Little brown bat.
Nycteris borealis borealis. Red bat.

But two species of bats, the only aerial mammals, were taken. It is useless to list here the birds seen, as the list would include virtually every species noted in the region.

BURN AND CLEARING

Grass-field habitat:

Lampropeltis triangulum triangulum. Milk snake. Rare.
Corvus brachyrhyncos brachyrhyncos. Crow. Abundant.
Molothrus ater ater. Cowbird. Common.
Sturnella magna magna. Meadowlark. Common.
Astragalinus tristis tristis. Goldfinch. Occasional.
Pooecetes gramineus gramineus. Vesper sparrow. Abundant.
Spizella passerina passerina. Chipping sparrow. Common.

Planesticus migratorius migratorius. Robin. Common.
Sialia sialis sialis. Bluebird. Numerous.
Scalopus aquaticus machrinus. Mole. Occasional.
Mephitis mephitis nigra. Skunk. Common.
Taxidea taxus taxus. Badger. Reported.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Occasional.
Sylvilagus floridanus mearnsii. Cottontail. Numerous.

Several extensive areas of dry grass-land were found. Some of these are former cultivated fields which have been allowed to revert to a wild condition. On the other hand, some of them are almost certainly primitive. They are covered with short grass (dry during the summer months), and, usually, milkweed, butter-and-eggs (*Linaria vulgaris*), mullein, and other herbs. No stumps or logs are found in this habitat. Grasshoppers are very common.

Sumach habitat:

There are distinct areas throughout the region, in which dense growths of sumach are predominant, with an undergrowth of grasses, milkweeds, goldenrod, and tall ferns. No collecting was done in these habitats, and no forms can be listed.

Overgrown-clearing habitat:

Thamnophis sirtalis sirtalis. Garter snake. Common.
Zenaidura macroura carolinensis. Mourning dove. Occasional.
Buteo platypterus. Broad-winged hawk. Occasional.
Haliaeetus leucocephalus leucocephalus. Bald eagle. Occasional.
Dryobates pubescens medianus. Downy woodpecker. Common.
Sphyapicus varius varius. Sapsucker. Numerous.
Melanerpes erythrocephalus. Red-headed woodpecker. Numerous.
Colaptes auratus luteus. Flicker. Numerous.
Archilochus colubris. Ruby-throated hummingbird. Occasional.
Tyrannus tyrannus. Kingbird. Common.
Sayornis phoebe. Phoebe. Common.
Cyanocitta cristata cristata. Blue jay. Common.
Molothrus ater ater. Cowbird. Numerous.
Astragalinus tristis tristis. Goldfinch. Common.
Pooecetes gramineus gramineus. Vesper sparrow. Abundant.
Spizella passerina passerina. Chipping sparrow. Abundant.
Melospiza melodia melodia. Song sparrow. Abundant.
Pipilo erythropthalmus erythropthalmus. Chewink. Common.
Passerina cyanea. Indigo bunting. Rare.
Toxostoma rufum. Brown thrasher. Occasional.
Sitta carolinensis carolinensis. White-breasted nuthatch. Common.

Penthestes atricapillus atricapillus. Black-capped chickadee. Common.
Planesticus migratorius migratorius. Robin. Common.
Sialia sialis sialis. Bluebird. Common.
Scalopus aquaticus machrinus. Mole. Occasional.
Nycteris borealis borealis. Red bat. Occasional.
Vulpes fulva. Red fox. Reported.
Lynx ruffus ruffus. Bay lynx. Reported.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Abundant.
Marmota monax rufescens. Woodchuck. Reported.
Tamias striatus lysteri. Chipmunk. Abundant.
Sciurus hudsonicus loquax. Red squirrel. Occasional.
Glaucomys sabrinus macrotis. Flying squirrel. Reported.
Lepus americanus americanus. Snowshoe hare. Reported.
Sylvilagus floridanus mearnsii. Cottontail. Common.

The clearings differ widely in degree of revegetation, but insufficient observations were made to warrant further division of this habitat. Berry bushes and many forms of herbaceous plants compose the first stage of reversion. Later, when birch, aspen, wild cherry, and other trees become dominant, the former plants form the underbrush. Usually there are many logs, stumps, and brush heaps, with a resultant abundance of cover. Chipmunks are the most conspicuous mammals in this habitat.

ARTIFICIAL CONDITIONS

Cultivated-field habitat:

Oxyechus vociferus. Killdeer. Abundant.
Corvus brachyrhyncos brachyrhyncos. Crow. Abundant.
Molothrus ater ater. Cowbird. Common.
Quiscalus quiscula aeneus. Bronzed grackle. Occasional.
Pooecetes gramineus gramineus. Vesper sparrow. Common.
Spizella passerina passerina. Chipping sparrow. Numerous.
Planesticus migratorius migratorius. Robin. Numerous.
Mephitis mephitis nigra. Skunk. Common.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Common.
Microtis pennsylvanicus pennsylvanicus. Meadow vole. Occasional.
Marmota monax rufescens. Woodchuck. Occasional.
Sylvilagus floridanus mearnsii. Cottontail. Occasional.

Cultivated fields comprise a great part of the area studied. They are planted with corn, potatoes, buckwheat, clover, and other products. Only random collecting was done in such places

and consequently the list of forms does not approach completeness.

Orchard habitat:

Bufo fowleri. Toad. Common.
Hyla versicolor versicolor. Tree frog. Rare.
Thamnophis sirtalis sirtalis. Garter snake. Abundant.
Dryobates pubescens medianus. Downy woodpecker. Common.
Sphyrapicus varius varius. Sapsucker. Numerous.
Tyrannus tyrannus. Kingbird. Abundant.
Sayornis phoebe. Phoebe. Numerous.
Cyanocitta cristata cristata. Blue jay. Numerous.
Quiscalus quiscula aeneus. Bronzed grackle. Occasional.
Astragalinus tristis tristis. Goldfinch. Common.
Passer domesticus. English sparrow. Common.
Pooecetes gramineus gramineus. Vesper sparrow. Abundant.
Spizella passerina passerina. Chipping sparrow. Common.
Bombycilla cedrorum. Cedar waxwing. Common.
Vireosylva olivacea. Red-eyed vireo. Numerous.
Dendroica coronata. Myrtle warbler. Occasional.
Troglodytes aedon aedon. House wren. Abundant.
Sitta carolinensis carolinensis. White-breasted nuthatch. Abundant.
Penthestes atricapillus atricapillus. Black-capped chickadee. Common.
Planesticus migratorius migratorius. Robin. Abundant.
Sialia sialis sialis. Bluebird. Common.
Mephitis mephitis nigra. Skunk. Common.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Abundant.
Rattus norvegicus. Norway rat. Occasional.
Marmota monax rufescens. Woodchuck. Occasional.
Tamias striatus lysteri. Chipmunk. Abundant.
Sciurus hudsonicus loquax. Red squirrel. Common.

Orchards are abundant in this region and are còmposed largely of apple, cherry, peach, and pear trees. A few are well cared for and the ground cultivated between the trees, and a few are planted with buckwheat, but the majority are allowed to grow wild, with only an occasional mowing. Often the trees are old and have hollows in them which chipmunks and bluebirds use as homes.

Edificarian habitat:

Bufo fowleri. Toad. Abundant.
Thamnophis sirtalis. Garter snake. Common.
Larus argentatus. Herring gull. On pier. Common.
Melanerpes erythrocephalus. Red-headed woodpecker. Occasional.
Chaetura pelagica. Chimney swift. Common.

Archilochus colubris. Ruby-throated hummingbird. Numerous.
Sayornis phoebe. Phoebe. Common.
Cyanocitta cristata cristata. Blue jay. Occasional.
Astragalinus tristis tristis. Goldfinch. Common.
Passer domesticus. English sparrow. Abundant.
Spizella passerina passerina. Chipping sparrow. Common.
Hirundo erythrogastra. Barn swallow. Nest. Common.
Bombycilla cedrorum. Cedar waxwing. Common.
Vireosylva olivacea. Red-eyed Vireo. Numerous.
Dendroica coronata. Myrtle warbler. Occasional.
Troglodytes aedon aedon. House wren. Abundant.
Penthestes atricapillus atricapillus. Black-capped chickadee. Common.
Planesticus migratorius migratorius. Robin. Abundant.
Sialia sialis sialis. Bluebird. Common.
Myotis lucifugus lucifugus. Little brown bat. Common.
Nycteris borealis borealis. Red bat. Numerous.
Mustela noveboracensis noveboracensis. New York weasel. Occasional.
Mephitis mephitis nigra. Skunk. Occasional.
Peromyscus leucopus noveboracensis. Northern deer-mouse. Abundant.
Rattus norvegicus. Norway rat. Common.
Sciurus hudsonicus loquax. Red squirrel. Numerous.

This habitat includes all buildings and their immediate surroundings.

ANNOTATED LIST OF MAMMALS

Scalopus aquaticus machrinus (Rafinesque). Prairie mole.

This mole is not uncommon in cleared places in the county. Burrows were seen along the roadside in sandy soil, near Traverse Lake; in a clearing on Pyramid Point; and along the roadside near the forest edge north of Leland.

Condylura cristata (Linnaeus). Star-nosed mole.

Conditions suitable for the star-nosed mole are not common and the community in which I obtained my single specimen was the only such place I found. This was at Duck Lake, where I found two series of burrows running close to the surface of the mucky shores, from areas of heavy cattail or grass growth to the open water.

Blarina brevicauda talpoides (Gapper). Short-tailed shrew.

The only place that this shrew seemed to be abundant was in a forest two miles north of Leland. Here they were the

dominant small mammal and the forest floor was an intricate network of their tunnels. During the first few days of trapping if a trap was placed at the entrance to a tunnel it was almost certain to contain a shrew in the morning.

One female was taken in a live trap and had eaten about half an ounce of fox-squirrel flesh placed therein. She had voided a great many feces and her abdomen was quite drawn. She had apparently starved to death. The trap had been out seventeen hours.

Myotis lucifugus lucifugus (LeConte). Little brown bat.

Three specimens of this bat were taken from houses in Leland during the summer. It is not uncommon about houses and barns.

Nycteris borealis borealis (Müller). Red bat.

Two red bats were brought in during the summer. One had been killed with a short club as it flew around a street light in Leland, and the other had been killed while flying about in a house.

About 1916 while on North Manitou Island I saw a red bat hanging in a hollow stub, exposed to a moderate degree of sunlight, and not over eight feet from the ground.

Ursus americanus americanus Pallas. Northern black bear.

On May 21, 1921, in the channel of Glen Lake, one-half mile west of the bridge, Volney Dorsey of Empire shot a bear. The animal was a male and weighed one hundred and thirty-nine pounds. It was reported that a bear and two cubs were seen a short distance from here. The land near here is largely covered with a deep hardwood forest, although there are many open fields too.

W. E. Hastings says that many years ago bear were common in Leelanau County and that in the summer of 1900 he saw some in Solon and Bingham townships. A resident of Shalda says that twenty years ago, along Traverse Creek, he killed one that weighed four hundred pounds.

Canis lycaon Schreber. Timber wolf.

Littell[3] in referring to the time about 1850, writes, "There were fur-bearing animals, wolf, fox . . ."

Canis latrans Say. Coyote.

I have no records of coyotes occurring in Leelanau or adjoining counties. Oscar H. Petersen of Northport writes: "I am quite certain that no coyotes have ever inhabited the country." A possible record is a note from Judge Martin Brown saying that wolves occur on the Fox Islands.

Vulpes fulva (Desmarest). Red fox.

Foxes are fairly abundant in the less settled parts of the country. I have found tracks and burrows in several localities, and they have been reported in many more. Around Pyramid Point they are often hunted with dogs in the winter months. In the *Leelanau Enterprise* of January 26, 1922, in the report of the County Committee on Bills and Accounts, there is a record of the payment of bounty on eight foxes. In the same paper for March 23, 1922, there is the following item: "Walter Hinshaw has returned from North Manitou Island with eleven fox hides." Robert Prause of Leland took several on this island in the winter of 1920–1921. Mr. L. V. Ruckel of Shelby, Michigan, writes that "A Mr. Hall who once kept light on the South Fox Island claims that fox have once or twice crossed from the mainland to the islands on the ice."

Urocyon cinereoargenteus cinereoargenteus (Schreber). Gray fox.

The only record I have for the gray fox in the county is contained in a letter from W. E. Hastings in which he notes that they were numerous in 1908 and formerly common. He took several in 1904 and 1905.

Procyon lotor lotor (Linnaeus). Raccoon.

Many tracks were seen about the border of Bass Lake, where a hardwood forest containing many large hollow trees

[3] Littell, *op. cit.*

comes very close to the water's edge. I had a raccoon in a trap here, but it was stolen before I arrived.

W. E. Hastings reports it as being common in 1908. Lloyd Huelett of Shalda says that in the winter he traps many raccoons and that a man living near there caught four alive in July, 1921, and killed a large female. The late Judge Meyers, of Indianapolis, told me that he had found tracks along a stream near Omena.

Martes americana americana (Turton). Eastern marten.

W. E. Hastings reports that marten formerly occurred in Leelanau County and that he took several there in 1904 and 1905; that it was abundant in Kasson and Bingham townships before 1875; and that he has heard trappers tell of making large catches each fall. He shot one while partridge-hunting about 1904.

Gulo luscus (Linnaeus). Wolverine.

W. E. Hastings writes: "When a boy, I saw one killed in a swamp in Leelanau County, 1898 or 1899, Bingham Township. Alfred LaFonze, Tom Molton, and William Emerson, old hunters and trappers, were in the party."

Mustela noveboracensis noveboracensis (Emmons). New York weasel.

Weasels seem to be abundant in the county and were easily trapped. All specimens taken were near some body of water, although they have been seen in other localities.

One adult male was discovered by Mrs. Julius Prause, in her hen-house. She picked it up by the tail and clubbed it to death. Two males, one a juvenile and one an adult, were trapped on successive days at the entrance to a small burrow at the foot of the clay bluffs along Lake Michigan. The hole was at the foot of a dead birch and around it was a scattered growth of annuals. Immediately in front of the entrance was a small bush, but on the whole the entrance was scarcely con-

cealed at all. The animals when found were outside the hole. When approached they made no noise, showed no signs of fear and none of fight.

Another adult male was taken in a trap, baited with a red-squirrel carcass, near a small burrow a few feet from Duck Lake. The hole was under a stump on a hillside which was covered with a heavy growth of young trees. This weasel did not show any fight either, but smelled strongly of musk when approached.

Mustela vison mink (Peale and Beauvois). Northeastern mink.

Tracks of mink were frequently seen along the shores of the smaller lakes and of the trout stream which enters the northern end of Lake Leelanau. At noon on July 17, 1916, I was fishing near the mouth of this stream and noticed a fully grown mink approaching along the lake shore. It kept in the line of drift-wood, and as it came to the stream started crossing on a log. When in the middle it stopped, looked at me for a moment, and went on, disappearing in the forest at the edge of the lake.

Mephitis mephitis nigra Peale and Beauvois. Eastern skunk.

Skunks are common throughout the area trapped, although not so abundant as most people think, for after one case of a skunk becoming offensive a dozen are usually reported to be hiding under various houses within two miles of the original source of the odor. They seem to prefer the borders of fields near swamps or forests and are often found in the immediate vicinity of the villages.

On one open clay slope five dens were found within three hundred feet of one another; while five hundred yards away at the edge of a leather-leaf bog and hidden among the ferns, briars, and wild-cherry were five holes, all within one hundred feet of one another. I caught four skunks in these five holes, some of them apparently young of the year. One of the entrances was large, but the others were usually five inches high and four and one-half inches broad. With one exception there was no loose dirt, odor, or refuse about the dens. The exception had a considerable amount of excavated soil in front of the den.

Immediately after I left one of these holes one time, a boy who was with me looked around and called my attention to a "white cat" that was walking out of the den. The specimen was a very white skunk which moved unconcernedly away from us and entered another den. We followed and were surprised to see him come out again and head for still another hole. He was driven back with rocks however and was trapped the next day at another hole some two hundred feet away.

On several occasions the distance that the animals ejected their scent was measured and found to be from six to ten feet.

A few years ago some skunks were turned free on North Fox Island for fur-raising, but as far as is known, skunks do not occur naturally on any of the islands.

Taxidea taxus taxus (Schreber). American badger.

Mr. Dago of Maple City is reported to have taken a badger near Bass Lake several years ago. If the badger does occur in the county it is very rare.

Lutra canadensis canadensis (Schreber). Canada otter.

Oscar Petersen, a forty-seven-year resident, writes that when he was a boy, otter signs were found on the shore of Lake Michigan, where he was raised. W. E. Hastings reports that in 1908 they were rare in the county and extremely rare in 1920. Lloyd Huelett tells me that a few years ago he and some others saw an otter in Traverse Creek.

Lynx canadensis canadensis Kerr. Canada lynx.

No good records of the wild cat are available, as the residents do not distinguish clearly between this and *Lynx ruffus*. All records of the wildcat have been here tentatively referred to the latter.

Lynx ruffus ruffus (Guldenstaedt). Bay lynx.

A few lynx are left in the county but not many. The author saw one south of Fouch about 1917. Sonny Ribble, a resident,

says that a few are taken occasionally. Lloyd Huelett of Shalda says that one was killed near Pyramid Point a few years ago. Mr. Carlson reports that they are occasionally heard in the winter on the northeastern shore of Lake Leelanau. Volney Dorsey of Empire writes that one was seen at the head of Glen Lake in 1920. W. E. Hastings writes that they used to be common in the county, but are now rare.

Peromyscus leucopus noveboracensis (Fischer). Northern white-footed deer mouse.

Peromyscus is the most abundant mammal in most of the terrestrial communities in which there is shelter. Several specimens were taken in live traps. When turned free each ran a short distance, and then apparently forgot my presence, and started searching for food under the leaves.

A female taken on September 7 was in milk. She was unusually large, having a total length of 190 mm.; tail, 91 mm.; hind foot, 21 mm.; and ear from crown, 17 mm.; and weight, 26.3 grams.

Synaptomys cooperi Baird. Cooper lemming vole.

One specimen was taken along the bank of Traverse Creek and another by Edward Butler at the edge of a cedar swamp at Nedow's Bay on Lake Leelanau.

Evotomys gapperi gapperi (Vigors). Red-backed mouse.

The red-backed mouse is abundant near the stream in the cedar-swamp at the northern end of Lake Leelanau. Most specimens were taken under logs that were elevated above the ground. There are no runways here as the ground covering is scanty. This species has never been found as far south in Michigan before.

Microtis pennsylvanicus pennsylvanicus (Ord). Meadow vole.

Microtis was not found abundant in any of the communities, although it is probable that it occurs in large numbers in some localities.

Rattus norvegicus (Erxleben). Norway rat.

The rat is abundant in the villages and on some farms, throughout the country. On one of the farms it was often possible to see eight or ten rats at one time, near the barn, the orchard, or the corn field. It is not cautious in the presence of men, but is very wary of traps. The rats have of course come in after the country was settled. It is reported to occur on North Fox Island.

Mus musculus musculus Linnaeus. House mouse.

No specimens of this mouse were obtained, although it is certainly present. Considerable trapping was done in the houses and stores of Leland, but the only mice taken were white-footed.

Ondatra zibethica zibethica (Linnaeus). Northern muskrat.

The muskrat is not uncommon where shores with Typha and other food and nesting material occur. It is practically absent in the northern end of Lake Leelanau, because of the barren and gravelly shores that prevail there. In the narrows near Provemont, where aquatic vegetation is abundant, it is quite numerous. About August 11, houses were well under way in the autumn construction. A very few live at Duck Lake (See Plate XXVI, Fig. 1), probably in burrows, for no houses have been found there. I am told that it does not occur on the Fox Islands.

On August fourth, at Duck Lake, I found a front foot of a muskrat in one of my traps. The animal had cut this foot off just above the jaws of the trap. In another trap was a large male held by but one toe, on the right hind foot. He showed considerable fight.

August 4, 1921, at Duck Lake, I found a canal which muskrats had constructed from the open water through a floating mat of Chara, pond-weed, and duck-weed, which was some fifty feet wide, to the cattail rushes. They had dug through a firm muck soil here, about thirty feet into this habitat. The canal averaged eight inches in depth and twelve inches in width. From its terminus several paths radiated out among

the cattails, and at the head of the canal there was an open space of about twenty-five square feet, cleared of rushes. A number of leaves of the cattail, about three feet long, were lying here with their butts towards the water. Pieces farther down the canal were cut into ten-inch lengths. One muskrat was taken in the canal and another in the clearing at its end. A photograph of the outer end of the canal is shown in Plate XXVI, Fig. 2.

Erethizon dorsatum dorsatum (Linnaeus). Canada porcupine.

W. E. Hastings reports that porcupines were common in the county in 1905, and Oscar H. Petersen of Northport tells me that they still occur. Mr. Woodbridge, of Indianapolis, saw one at the north end of Lake Leelanau about six years ago. Residents of the Pyramid Point district say that they are occasionally seen. Christian Andresen had his dog return home with its nose full of quills on two occasions in 1921. In that region I found one tree which had recently been girdled by a porcupine. They are not known to occur on the islands.

The Indians of the county have probably been responsible for the disappearance of the porcupine, as they use the quills to a large extent in decorating birch-bark baskets.

Marmota monax rufescens Howell. Rufescent woodchuck.

The woodchuck is common in the county, although many localities seemed to be without it. Several holes that I was shown in open fields, as woodchuck holes, when trapped, produced only skunks. The county pays a bounty for these animals and their local scarcity may be partly accounted for in this way. The one specimen taken, a juvenile, was caught at the entrance to a burrow in a clover field. There were five holes all within twenty feet of the one in which he was caught.

Tamias striatus lysteri (Richardson). Northeastern chipmunk.

Martin Brown of Leland, and L. V. Ruckel of Shelby, tell me that these animals are found on the Fox Islands. Strang [4]

[4] Strang, James V. *Fauna and Flora of Beaver Island. Ninth Ann. Rept. Smithsonian Institution,* p. 282. 1854.

lists the chipmunk among the fauna of Beaver Island, which is just one island north of these islands. In view of the fact that these animals are so lethargic during the season that the channel between the mainland and the islands is frozen, it is not probable that they gained access to the island over the ice. I have no record of their occurrence on the Manitou Islands.

Sciurus hudsonicus loquax Bangs. Southeastern red-squirrel.

The red squirrel is the most abundant squirrel of the county, and was especially numerous during 1921. Edward Butler of Hubbard Woods, Illinois, writes that during 1922 it was greatly reduced in number at Leland. This fluctuation seems to occur quite normally in the county, although I have no records of their periods of maximum and minimum abundance. It was a serious pest during 1921, damaging a considerable amount of fruit, and gnawing into several houses. In one house which had been entered it was possible to keep the squirrel out only by shooting. Martin Brown says that it occurs on the Fox Islands.

Sciurus carolinensis leucotis (Gapper). Northern gray squirrel.

In several places, notably in Day's Forest, on the north shore of Glen Lake, the gray squirrel is abundant. The black phase greatly outnumbers the gray phase, although intergrades occur and only rarely is a very black specimen seen.

Sciurus niger rufiventer (Geoffroy). Fox squirrel.

The fox squirrel is not numerous in the county. It is found only in the more open woods where there are tall oaks, beeches, and sugar maple, and where there usually is a slight shrubby undergrowth. On one occasion I was attracted to the woods by an evident amount of excitement among the squirrels. After a short time I was able to locate twenty red squirrels and two fox squirrels. One fox squirrel was being pursued by an excited red squirrel, and the chase ended only when the fox squirrel was shot.

A specimen taken July 29 showed little fat, but the three other specimens taken later in the summer had heavy layers of fat over the abdomen, between the shoulders, and about the kidneys. The average weight was 817 grams.

The fox squirrel is more shy than the red and gray squirrels, and keeps high up in the trees when it is aware of a man's presence.

Mr. Klauss of Leland says it occurs on North Manitou Island.

Glaucomys sabrinus macrotis (Mearns). Canada flying squirrel.

The only specimen of a flying squirrel which I obtained was the tail of one found on the gravelly beach on the edge of Lake Leelanau, at the edge of a heavy hardwood forest. Dr. W. M. Payne of Suttons Bay says that he has had one in captivity, and Oscar Petersen of Northport says that he has had a number of them caged. I have a dozen other apparently reliable records of flying squirrels having been seen or taken in the county.

Castor canadensis michiganensis Bailey. Woods beaver.

The beaver is undoubtedly extinct in the county, and I could find no trace of its occurrence; but W. E. Hastings, formerly a resident of this region, writes that old dams are still found in the county.

Lepus americanus americanus Erxleben. Snowshoe hare.

W. E. Hastings writes that in 1920 the white rabbit was still common. Residents of the Pyramid Point region told me that this hare is abundant there. Many residents of Leland said that it is found in the cedar swamp at the head of Lake Leelanau and in winter comes down as far as Leland. Judge Martin Brown writes that it is found on the Fox Islands and Mr. Carlson has told me that it is found on North Manitou.

Sylvilagus floridanus mearnsii (Allen). Mearns cottontail.

The cottontail is fairly abundant in the county, although it has probably migrated into the region since the land was

cleared. Mr. Klauss of Leland says that it occurs on North Manitou Island and Martin Brown writes that it occurs on both the Fox Islands.

Cervus canadensis canadensis (Erxleben). Wapiti or Elk.

In 1920 a complete skull bearing a large pair of antlers, together with most of the skeleton of an elk, was found in excellent preservation in a quaking bog at the edge of Prause Lake near Shalda, by John Shalda. I examined the place where the bones were taken and it seemed apparent that the animal had become mired in the soft bog and died there. An old inhabitant of the region says that about sixty years ago a very large deer was seen in that region but was never shot. The antlers have seven prongs, extend forty-three inches above the crown of the skull, and have a maximum spread of forty-three inches.

Odocoileus americanus borealis Miller. Northern Virginia deer.

Littell[5] quotes Alexander Mason, Jr., as stating that about 1865, deer were plentiful. In a letter, Oscar Petersen, of Northport, a resident of forty-seven years, says: "In my younger days deer were occasionally found in this section." W. E. Hastings writes that there are still a few in Grand Traverse county and probably in Leelanau (1921).

Alces americanus Jardine. Eastern moose.

No moose are resident in the county at the present time. Littell[6] in referring to the game present at the time of settlement says: "Game of many kinds was plentiful except the larger game, deer, elk and moose, which were found farther south because they had to come south in their winter migration east of Traverse Bay." Little or no weight, however, is to be attached to Mr. Littell's theory as to the absence of the moose.

Mr. Huelett of Shalda says that about twenty-three years ago he killed a "large deer" which had flat antlers with a

[5] Littell, *op. cit.*

[6] Littell, *op. cit.*

spread of about four feet, and whose hair was very dark, and over the back was quite long. This is almost certainly a record. There is little doubt as to their former occurrence here, for there are several records for moose in the Lower Peninsula of the state, although they are now totally extinct there.

University of Michigan

PLATE XXIV

Fig. 1. Lake Leelanau, North of Nedow's Bay, showing Character of Lake Border.

Fig. 2. Grass Field Habitat, at Edge of Forest, Leland.

PLATE XXV

Fig. 1. The Lake Michigan Shore, near Leland.

In the middle are clay-bluff and open-beach habitats.

Fig. 2. Region near Pyramid Point, showing Typical Topography and Vegetation in This Section of the County.

It was on the shores of the lake shown here, that the skeleton of the elk mentioned in the annotated list was found.

PLATE XXVI

FIG. 1. South Shore of Duck Lake, showing Mud-Flat, Cattail and Willow-Thicket Habitats.

FIG. 2. Canal Constructed at Duck Lake by Muskrats.

A COLLECTING TRIP TO BRAZIL

JESSE H. WILLIAMSON

INTRODUCTION

During the late summer and autumn of 1921 plans were made by Dr. Ruthven, director of the Museum of Zoölogy, University of Michigan, and Mr. E. B. Williamson, honorary curator of Odonata, of the Museum of Zoölogy, to send an expedition to the upper Amazon River to collect specimens for the Museum. Shortly thereafter political disturbances near Iquitos, Peru, made it impossible to secure transportation by established lines beyond Manáos, Brazil. It was, therefore, left to the discretion of the members of the party, Captain John W. Strohm and myself, both of Bluffton, Indiana, to work northwest of Manáos along the Rio Negro or southwest on the Rio Madeira. Dr. Hamilton Rice of Boston furnished valuable information about conditions generally along the Rio Negro; but after conversations with Mr. Henry S. Fleming, consulting engineer, in New York City, and Mr. F. Packer, general manager of the Amazon River Steam Navigation Company at Pará, Brazil, we decided it would be more feasible to work along the Rio Madeira. Our main efforts in the field were to secure and preserve dragon-flies, and incidentally to collect such other insects, reptiles and amphibians as could conveniently be taken care of. The trip is to be known officially as *The University of Michigan-Williamson Expedition to Brazil.* The account of the field work which follows is to serve as a basis for the detailed papers which will appear from time to time.

NARRATIVE

Captain Strohm and I sailed from New York on December 15, 1921, on the Booth Line SS. "Polycarp" direct to Pará,

Brazil, where we landed December 30. The true name of the city is Belém, but following a custom in Brazil, it is generally called by the name of the state of which it is the capital. The American consul, Mr. George Pickerell, kindly accompanied us to the custom-house, where, through courtesy of the Brazilian government, our baggage and equipment were admitted free of duty. The next five days, while we were waiting for an up-stream steamer, were well spent in gaining information and making arrangements relative to the trip into the interior.

On January 5, 1922, we boarded the SS. "Paes de Carvalho" of the Amazon River Steam Navigation Company, and travelled quite comfortably among heavily wooded islands and through *paranas*, or side channels, till we emerged on the Amazon River two days later. Several stops were made daily to take on or discharge cargo and passengers or to load wood for fuel. At such times we were frequently able to go ashore and catch a few dragon-flies.

On January 8 we anchored off Santarem for a few hours and that evening as we continued up-stream, we saw at least a dozen Gynacanthas or Tholymis hawking out over the river. This was not an uncommon sight on the Amazon for twenty or thirty minutes just after sunset.

Early on the morning of January 9, the steamer stopped about one-half mile below Obidos to load cattle. This gave us an opportunity to collect along a small muddy creek and several swampy areas in a pasture field nearby. Six species of libellulines and two of coenagrionines were added to our list. When we again reached Obidos six and a half months later, the river was at flood stage and the pasture field covered with several feet of muddy river water.

We passed the state line from Pará into Amazonas during the night of January 9 and shortly thereafter reached Parintins. Here the steamer left the Amazon River to go by *paranas* to the town of Maués, the center of the guarana industry. We returned to Parintins by the same route and continued up the main river. Diastatops was taken in grass growing six feet

high along the river bank, at a *fazenda* named Progresso, where the steamer stopped to load grass for the cattle on board.

We tied up at the bank at Itacoatiara on January 12 and five hours later passed the mouth of the Rio Madeira. The following afternoon, we passed from the yellow, muddy Amazon into the almost black waters of the Rio Negro and soon docked at Manáos, eight miles above the confluence. The floating docks at Manáos were twenty feet below the 1909 high water mark of the Rio Negro. On our return in June the river had exceeded that record by several inches and the docks were well above the lower streets of the city. The difference between high and low water marks is said to exceed fifty feet. Clouds and drizzling rain prevented collecting during our two days in port.

We sailed at 10 P.M. on January 14 and the next morning found us on the Rio Madeira, the largest tributary to the Amazon — at this season a turbulent, muddy stream seemingly as large as the Amazon itself. On January 16 we passed Borba, Tabocal and the mouth of the Rio Duvida or Roosevelt River, whose clear waters contrasted sharply with the yellow flood of the Madeira. Again just after sunset dragon-flies hawked about in mid-channel.

On January 17 we collected at the town of Port Arthur and Manicoré. At 6 P.M. the steamer tied up near several woodpiles at Boca de Capaná. Tholymis flew by hundreds over the water, around the woodpiles and farther inland over the high grass. As the result of many wild strokes with the nets, nineteen were captured. Soon moths, mosquitoes and other insects were attracted by the electric lights of the steamer and countless frogs began croaking in nearby swamps. It was quite a relief to get under way again at 9 P.M.

The following day a few common libellulines were caught during short stops at Novo Olinda, Uruapiara and Bom Futuro. Tramea, Erythemis, Erythrodiplax and Orthemis were among the day's catch. On January 19 several stops were made, but they were too brief to permit our going ashore to collect. When the steamer docked at Humaytá about 6 P.M. we hoped to catch another series of Tholymis, but only one was seen. Floating

trees and débris that evening indicated another flood with the river out of its banks higher up.

At 1 A.M. on January 20 I awoke to find the steamer tied up at a woodpile called Mirary. I spent the next two hours there gathering up beetles and cicadas that had been attracted by the electric lights. During the day we worked for short periods at Firmeza and Assumpcão. Due to an approaching storm dusk came earlier than usual and from 5:50 to 6:10 P.M., while tied up at the woodpile of São José de Praia, we succeeded in netting both sexes of Gynacantha. Ten minutes later the rain started. At this woodpile, surrounded by virgin Amazonian forest, we remained till dawn, pestered all night long by swarms of mosquitoes. It was the first time that I had occasion to use a mosquito net over my cot on the open deck and the only night made sleepless by insect pests that we experienced during the ten-months' trip. Collecting en route yielded 20 species and only 156 specimens of Odonata.

Shortly after dusk on January 21 we docked at Porto Velho, state of Amazonas, the third largest Brazilian city in the Amazon basin, eighteen hundred miles from Pará. It is the northern terminus of the Madeira-Mamoré Railway which extends southwestward two hundred and twenty-five miles, all but the first four kilometers of which were in the adjoining state of Matto Grosso. The line follows more or less closely the right banks of the Madeira and Mamoré rivers. The Madeira-Mamoré Railway Company, hereafter referred to as the Company, maintains well-screened buildings equipped with telephones, electric lights and shower baths, for its officers and many of the employees. The Hotel Brazil, owned by the Company but leased to private interests, is similarly equipped for the convenience of guests. Here, as everywhere on the trip, ice was obtainable for personal and photographic purposes. Porto Velho is sixty meters above sea level, in Latitude 8° 46[1] South, Longitude 63° 55[1] West. It was our base of operations for the ensuing four months.

From January 21 to March 5 and from April 18 till May 30, we collected in and near Porto Velho when weather conditions

permitted. The original heavy forest had been cut away for at least a mile back from the river, but within this area there were sufficient second-growth trees and bushes to furnish shelter for some species of dragon-flies along several streams and around a deep lagoon filled with back-water from the river. Erythrodiplax, Tramea and Orthemis flew on sunny days in most parts of the town itself, and occasionally we caught Gynacanthas at dusk in the railroad yards. A small waterfall in the eastern part of town and the same creek in the vicinity of Barbados Hill furnished convenient places to collect during short periods of sunshine on more or less rainy days.

By following cart roads and mule paths for about two miles north of town, we found several small creeks in the forest. They were similar in character, two to three feet wide, ankle- to hip-deep with soft muddy bottoms, flowing in well-wooded ravines among dense undergrowth. Here we found Acanthagrion, Argia, Chalcopteryx, Hetaerina, Heteragrion, and other woodland stream genera. Where an occasional clearing extended down to the creeks, several genera of libellulines including Erythemis, Nephepeltia, Erythrodiplax, and Oligoclada were taken. In the neighboring woods we took large numbers of Uracis and smaller series of Metaleptobasis and aeshnines. Logging roads on the wooded hills afforded favorable collecting places for *Gynacantha membranalis.* Farther east in the woods was a much larger stream, too deep to wade, flowing swiftly between high, steep earthen banks. Several visits to this larger stream yielded very few specimens and nothing different from the smaller creek species.

On a scouting trip south of town along the railroad we came to several flooded creek basins. Where the banks had been cleared we found little of interest; where forested, these flooded basins could not be worked either from the banks or by wading. It was necessary to strike all creeks far back from the main rivers during the flood period which prevailed during our trip into the interior. The banks of the large rivers supplied nothing of interest during the months we were there. A small creek back of Candelaria, the Company's hospital, flowed mainly

through cultivated or pastured fields and proved disappointing. Where it entered the woods, tangled vines, fallen trees, dead branches and mucky bottom made progress practically impossible and a little farther down there was back-water from the Madeira.

Another scouting trip took us northeast of town for about two miles, following muddy trails over cleared ground and then through partially cleared forest. En route, we collected at puddles and temporary running water the more common swamp species. We finally came to a clear-water creek, knee-deep, from five to twelve feet wide, flowing in an earth-banked channel ten to twelve feet deep through a large, cultivated clearing. We caught nothing on this part of the creek. Working upstream to its source in the woods yielded few specimens. In the forest Uracis was plentiful. At a circular depression in the woods, some thirty feet in diameter, *Gynacantha gracilis* was taken in series. The females were comparatively easy to catch, but all of the males were shot with dust shot. Near the edge of the forest was a thick, tangled growth of shrubs, vines and weeds through which surface water drained after heavy or continued rains. Here, hovering or flying in quick, short darts a few inches above the moist earth and leaf mold, in very dense shade, occurred a much smaller species of aeshnine.

We spent January 29 as guests of Messrs. Leonard and Arthur Craney and W. R. Goodwin on one of the Company's launches. After going several miles down the Rio Madeira, which was reported to be forty feet above low water stage, we entered several creek basins and navigated among tree-tops with flooded woodland on all sides. Only a few dragon-flies were caught, but we secured quite a collection of ants and spiders that fell into the launch along with twigs and bark as we bumped and crashed through the branches.

We made arrangements with Mr. W. J. Knox-Little, general manager of the Company, for a trip by gasoline motor-car from Porto Velho to Guajara Mirim to locate favorable collecting points along the railroad. The round-trip was made on February 7 and 8; we passed the night as guests of the Company

in the house maintained for its officials at the southern terminus. We noticed creeks at kilometer posts 50, 53, 61, 64, and 71 before we crossed the flooded Rio Jacy-Paraná near the town of the same name at kilometer post 88. As we sped along Gomphoides were caught on the fine-meshed wire screen at the front of the car, between kilometer posts 87 and 91, which we passed about 9 A.M. We passed other creeks near kilometer posts 123, 129, 142, 187, 204, 205, 206 and 216. All regular trains stay over night at Abuná, kilometer 220, where the Company maintains a very good hotel. We lunched there and then continued our journey. Other creeks were noted near kilometer posts 225, 289, 291, 306, 308 and 309 before we reached Villa Murtinho at kilometer 313, where only restaurant facilities are available for travelers.

Near kilometer post 341 more Gomphoides were caught on the wire screening, from which four species of other genera, new to our list, were taken during the day's run. For practically the entire route covering three hundred and sixty-three kilometers, the right of way is bordered by heavy forest, cut off in some places to supply fuel for the engines. A notable exception to this condition occurs between kilometers 170 and 216 where a tangent leads straightaway across a swamp. In this district were stunted trees, almost leafless, and for several kilometers only swamp grass and a single species of palm tree. The flooded Mutum-Paraná, Araras, Riberão, Lage and Bananeiras rivers were crossed near kilometer posts 168, 261, 290, 319 and 350 respectively, each being navigable by launch and impracticable to work during the high waters. Just at dusk we arrived at Guajara Mirim, one hundred and forty-five meters above sea-level, eighty-five meters higher than Porto Velho. On the return trip two more species were added at the creek near kilometer post 123.

On February 19 Messrs. Leonard Craney, Goodwin, Anderson and Menezes supplied horses and led the way to the best collecting locality near Porto Velho. The city water-supply creek has its origin in three springs, each at the head of a gully in the wooded hills three miles east and a little south of town.

Within one-half mile these gullies unite and form a mud-bottomed creek which flows for six hundred yards through a grass-covered ravine into an artificial pond near the site of a small tannery. At different times considerable collecting was done at and above the pond; both swamp and creek species were plentiful. A mile nearer town, well-wooded trails led to the same stream at a point where charcoal-burners had built a small camp on a hill-top, overlooking the heavily forested valley of the stream which at this time was shoulder deep and fifteen feet wide.

When we returned in April, it was only hip-deep and had vertical or overhanging earth banks two to four feet above the water level. The bottom was largely sand. A right bank tributary entered the stream here, but it was so full of logs and branches, and had such a treacherous bottom that wading it was not feasible. Below and to the right of the junction was a low flooded area of possibly ten acres, bordered by woods, cleared land and the tributary creek. It contained patches of of knee- to waist-high grass, clumps of green bushes rising eight to ten feet above the water, marsh grass ten feet tall with dead tassels, and some old logs and dead tree-tops.

On subsequent visits a few species of coenagrionines and many libellulines were taken here. Messrs. Goodwin and Craney later assisted in collecting at this and other localities. About one-fourth mile up the main stream a left bank tributary entered. This was followed up a narrow marshy valley between heavily forested hillsides to its source, but yielded few specimens. One-half mile farther up another left bank tributary furnished fine collecting. This creek was four to eight feet wide, ankle- to knee-deep with firm sand bottom for probably one mile; then the bed of the stream rose rapidly among boulders and rock faces till within another quarter mile all trace of running water was lost. Heavily wooded swamps drained into the tributary and main creeks and yielded Perithemis, Acanthagrion and the beautiful *Fylgia amazonica* with segments 1–5 of the abdomen black, 6–10 a brilliant metallic red. Gomphines, aeshnines, Chalcopteryx, Lais, Heteragrion, Hetaerina and

Argia occurred on the main and tributary creeks during April and May. Microstigma was caught in the woods close to the creek.

Upon leaving Porto Velho, March 5, the dragon-fly collection totalled 85 species and 2202 specimens. An all-day ride on the combined freight and passenger train brought us to Abuná at dusk. The official name of this town in the postal guide is Presidente Marquez, but it is seldom if ever used along the railway. It was our collecting base for the next three weeks. Here the Rio Madeira is only half as wide as at Porto Velho. Its sloping mud banks yielded no specimens.

March 6 we collected along drainage ditches, with muddy water six feet wide and knee-deep, on either side of the railway north of town. A small libelluline was taken in series, but was quite rare on subsequent visits to the same place. Lestes, Perithemis, Orthemis, a large black Tramea and several coenagrionines were taken on later visits to these ditches or along the border of the woods just beyond them.

Near kilometer post 216 the railroad crosses a stream fifteen to twenty feet wide and varying greatly in depth during the rainy season. At times it was only hip-deep; a few days later it was out of its banks and running knee-deep through the adjoining forest. At the bridge it was full of long, wavering, under-water vegetation whose leaves at the lower water stages protruded slightly above the surface and furnished resting-places for a small blue coenagrionine. For several hundred feet back from the track the forest had been cleared away. Here the banks of the creek were covered with clumps of bushes and scattered grass stalks eight to ten feet high. A species of a peculiar new genus of coenagrionines rested on the tips of the grass with folded wings or flew above them in irregular jerking flight. A larger series of this same species was taken from a clump of bushes around the center pier of the railroad bridge. An old foot-trail, in places almost obliterated by undergrowth, led southward along the left bank of the creek for several kilometers. Going slowly along the trail we picked up Metaleptobasis, Uracis, and an occasional aeshnine. Along the creek

Hetaerina and Lais were found in limited numbers. We also worked along the creek and woods trails north of the bridge.

On March 3 we walked the ties for five and one-half kilometers to a large back-water creek at kilometer post 225. This stream proved to be too deep to wade and could not be worked from the wooded banks, thickly overgrown with underbrush and vines. Sixteen specimens taken along the right of way constituted the day's catch.

A swampy pasture south of the station between the railroad and the Rio Madeira yielded some common species, including *Erythemis peruviana*, which was seen in very few localities on the trip. Sometimes we collected at a swamp in semi-cleared land about one-half mile north of the station near the river. It covered several acres, in sun and shade, and contained clumps of bushes, sedges, fallen trees, areas of open water and patches covered with floating vegetation. Small crocodiles and the reported presence of the venomous *surucucú* made collecting in this typical tropical swamp more than interesting. Leptobasis, Metaleptobasis, Lestes and aeshnines were found in a small, densely wooded tract on the northern side of the swamp.

Three quarters of a mile northeast of the Company's water-tank, and in the center of a large pasture field dotted with termite nests, a dam had been built below the confluence of two little creeks. The resulting crescent-shaped pond, forty feet long by twelve feet wide, teemed with dragon-flies when the sun shone brightly. As we followed trails on north through clearings and cultivated fields, several small creeks were crossed. These united to form a larger creek which we worked in the woods two miles north of Abuná. Perhaps these streams were seasonal and dried up completely later on; at any rate odonate life along them was quite scarce.

During our stay at Abuná we crossed the river to the Bolivian town of Manoa, where we were hospitably entertained by Señor Gonzales, the administrator of customs, and the officers of the army-post. Arrangements were made by the officers to take us on an extended trip into Bolivia, along the

Abuná and Negro rivers, but these and other plans were subsequently abandoned on account of sickness.

On March 15 we had a very pleasant evening with Drs. Mann, White and Pierson, the last members of the Mulford Expedition to leave Bolivia. We had seen Dr. Rusby, head of the expedition, at Manáos, on his way to New York.

When leaving Abuná, March 27, we had 107 species and 3616 specimens. We made the four-hour trip by train to Villa Murtinho and established sleeping and working quarters in a corner of the Company's restaurant. The flooded creek basin just north of town afforded good bathing, but very poor collecting. A trail leading east from kilometer post 312 passed over cleared land, second-growth pasture fields, along mandioca and corn fields, then over a low brush-covered hill of decomposed red rock. Three kilometers inland it entered a palm forest where Hetaerinas along the trail indicated the presence of a stream nearby. A little farther on it crossed a sandy-bottomed creek two to four feet wide and ankle-deep. Hetaerina, Heteragrion, Argia and Lais occurred in limited numbers.

The trail led on through palm forest, over several small hills and past an extensive new clearing into more forest. Again Hetaerinas were noticed along the trail which led into a small clearing on the right bank of a large creek. This, we were told, was the same stream that entered the Rio Madeira just north of town. Here it was twenty feet wide, five feet deep in mid-channel, with firm sand bottom and a swift current. A second species of the peculiar new genus first taken at Abuná was found resting on leaves on the tips of bushes along the bank.

The creek which the railroad crossed at kilometer post 309 soon played out in a bushy swamp that yielded nothing of interest to us. A trail led eastward near kilometer post 310 through a patch of timber, across an extensive clearing planted to mandioca, then into a low lying palm forest. There it crossed a tiny creek two feet wide with running water a few inches deep on which a few specimens of a gomphine, Heteragrion, Perilestes and Psaironeura were taken. Its source was a small grass-grown swamp bordered by palm forest on one side and cane on the

other. By following it down-stream we came to a larger creek with low mud banks in heavier forest where a troop of monkeys played in the tree-tops. No sunshine penetrated the dense foliage overhead and very little undergrowth of any kind existed amid these sombre surroundings. The very air seemed oppressive. Perithemis was the only representative of dragon-fly life found here. As we returned homeward, pools and ditches beside the railroad embankment yielded the same swamp species that we had found at Abuná.

Our best creek near Villa Murtinho passed under the railroad at kilometer 315. Down-stream its channel had been ditched and little of interest was found. Up-stream it presented varied conditions. For the first half mile it meandered through a low palm forest, at times in several channels each about six inches deep and two to four feet wide where a *machete* was frequently used to open up a passage; at one place it spread out among palms and shrubs to form a muck-bottomed pond twenty-five to thirty feet wide and varying in depth from a few inches to two feet. A short distance above the pond was slightly higher ground, with heavier timber. This point could be reached very easily by following a woodcutter's trail leading east from the track. For at least two miles farther up the stream flowed in a well-defined sand-bottom channel, eight to ten feet wide, through virgin forest. Along this stream three species of Perilestes were taken. Swampy areas in the woods with their small drainage channels leading to the creek enabled us to add several other interesting species to the collection.

On March 29 and 30 we were the guests of Messrs. Bell and Craney, Company officials, on a business trip to Guajara Mirim. Advantage was taken of this opportunity to scout territory in that vicinity. Only flooded creek basins were found there and near Porto Sucré on the Bolivian side of the Rio Mamoré. We therefore abandoned the plan of establishing temporary collecting quarters in the Company's house, kindly offered by Mr. Knox-Little for our convenience.

On the last evening at Villa Murtinho, April 7, the collection contained 127 species and 4585 specimens. The next day we

moved to Villa Bella, Bolivia, where we were entertained by the Company's local manager, Señor Carlos Cordova, and Mr. Georges Fasnacht of Suarez Brothers. Upon presentation of credentials, the customs officials admitted all baggage duty-free without inspection. On April 9, after a four hours launch ride up the Rio Beni, we landed below the rapids at Cashuela Esperanza and secured comfortable quarters at the hotel, which, together with the rest of the town and surrounding country, was owned by Suarez Brothers. The town site was on an outcropping of granite rock on the right bank of the river. Cleared pasture land nearby afforded a variety of open creek and swamp conditions. By following a broad trail which ran southeast through the woods to the Rio Yata, we came to several woodland creeks varying in width from two to eight feet. Practically identical species were found on each of them and for the first time Chalcopteryx was plentiful. In woods near the source of two of the creeks, Captain Strohm found Microstigmas pairing on April 13. Six strokes of his net bagged nine specimens. The next day we worked the same woods, but on account of continual clouds and several showers only two specimens were captured.

An attack of benign malarial fever kept me bedfast for the next two days. As no medical attention was available and my fever continued to rise, we left Cashuela Esperanza April 16, and spent three days travelling as rapidly as transportation facilities permitted to the Company's hospital at Candelaria. Captain Strohm secured our former rooms in the Hotel Brazil at Porto Velho and resumed collecting in that vicinity on April 24. After an interval of ten days, I joined in the work. Most of our time was spent in localities heretofore mentioned. Two short trips were made along the Rondon telegraph trail which runs for over a thousand miles through the interior of the State of Matto Grosso. Some collecting was also done along creeks near San Antonio, the western terminus of the telegraph line, located at the falls of the same name on the Rio Madeira. When we finally left Porto Velho on May 20, we had 137 species and 6588 specimens.

We were very much pleased to find Commandante João B. Moreirc, who had looked after our welfare so well on the up-river trip, in command of the Amazon River Company's SS. "Sapucaia." On it we made the five days journey back to Manáos. Below Borba the Rio Madeira was out of its banks surrounding isolated huts near the river and extending far back into the forest. Above the mouth of the Madeira, the right bank of the Amazon was likewise under water. Native huts stood half-submerged amidst flooded cacao and banana fields. Here and there small groups of cattle were helplessly marooned on rafts to which their owners brought fresh grass in dug-out canoes.

From June 4 to 30 and again from July 13 to 21 we collected near Manáos, the capital of the State of Amazonas. While there we were fortunate in being the house-guests of Mr. S. W. C. Russell, manager of the General Rubber Company of Brazil. Owing to the unprecedented high level of the Rio Negro, creek beds were flooded for over a mile back into the country. We collected along the brushy bank of the stream which flows past the Manáos brewery, finding there many teneral libellulines and two species of coenagrionines.

The back-water extended inland to the old dam, built across the creek bed a half mile below the Bosque and about two miles from the river. The artificially flooded area above the dam afforded but little better collecting grounds. Back of the Bosque, the creek was ten to fifteen feet wide and, in places, four to five feet deep. Partially cleared swampy woods along its banks contained dense undergrowth. Very few interesting species were found here. We did considerable collecting on the same creek higher up near Flores, the terminus of a street-car line seven miles from the city. Here the main stream was eight to ten feet wide, two to three feet deep, flowing through swamp grasses with occasional clumps of bushes along the banks. A left bank tributary, entering just above Flores, supplied a variety of swampy woodland habitats.

An automobile road led to Flores from the end of the Villa Municipal street-car line, a distance of about four and a half

miles. Several creeks similar in character, some too deep to wade, crossed this road. The country was rolling, with low hills that were or had been forested. The valleys were more or less swampy, open in places, but generally thickly overgrown with underbrush and small trees. Between the road and the Flores car line were several sand-bottomed ponds, varying from six to fifty feet in diameter. Anax occasionally visited the largest pond circled it a few times and then flew off over the tree-tops. Libellulines were numerous and several species new to our collection were secured here.

On June 18, accompanied by Mr. Russell, we walked for seven miles north of Flores along the road to Campos Salles. Five miles out we found a beautiful little creek in virgin forest. By the end of June, collecting near Manáos had brought the species list to 158, the specimen list to 8012.

On July 1, I suffered another attack of fever, not sufficiently serious however to alter our plan for a round-trip on the Amazon River Company's monthly steamer to Santa Isabel, four hundred and twenty-three miles up the Rio Negro. We found travelling here much the same as on the Amazon. Day after day we sailed between walls of green vegetation, sometimes close at hand as we passed among uncounted wooded islands, at other times fading away along the distant banks of the main river to mere lines on the horizon. Bird and insect life was noticeably scarce. The dozen widely separated settlements en route consisted of one to twenty houses each, generally closely surrounded by back-water from the still flooded river. It was only within fifty miles of Santa Isabel that low hills were seen and the river was confined within its banks.

On July 7 we went ashore at Santa Isabel and followed trails made by Brazil-nut gatherers for a mile back into the woods. A few muddy little pools in temporary drainage channels yielded no specimens. Uracis and Microstigma were taken in the woods. We returned to the river and spent most of the day at a back-water swamp, fifteen by fifty feet in dimensions, near the boat landing. Three species new to our collections were taken here. The following morning we started back to

Manáos. Though the steamer frequently stopped to load fire-wood and Brazil-nuts, there were few opportunities for us to go ashore.

From Carvoeiro to the mouth of the Rio Branco many teneral Diastatops and a few other libellulines came to rest on the ropes, rails and netting of the boat. Fellow passengers and some of the crew eagerly assisted in catching them by hand. At dusk on July 10 while we were anchored off Moura, large numbers of Tholymis hawked about over the river. Only two were netted. July 13 found us back in Manáos with only 93 specimens and 4 additional species from the eleven days' trip.

On July 21 we caught over one hundred specimens of *Aeolagrion flammeum* in Mr. Russell's home. They flew slowly about the rooms, generally coming to rest on the walls behind articles of furniture. Sometimes they rested on picture cords, electric light fixtures or on the bed clothing. On several occasions I noticed them attempting, usually unsuccessfully, to alight on the polished brass knobs of the bedsteads. We had previously taken smaller numbers of the same species in the house, yet we were never able to find a single specimen in the surrounding gardens. Mr. Russell states that at certain seasons he is bothered nightly by large dragon-flies flying in numbers around the electric light bulbs in his library. This did not occur during our visit, although one evening I caught a Tramea after it had repeatedly flown against one of the lights. A few other libellulines were taken, from time to time in the house. We sailed for Pará on July 22 with 162 species and 8315 specimens. During the seven days' trip no collecting was done.

At Pará we met Reverend Miles Moss, an enthusiastic lepidopterist, who took us on several field trips. He secured permission for us to collect in the city water-supply reservation, which furnished a great variety of swamp, pool, creek and woodland habitats. He also led the way to a fine creek in the woods about three quarters of a mile beyond the end of the "Souza" street-car line. This creek was eight to ten feet wide and from a few inches to two feet deep. Where we first entered, it had fine yellowish sand bottom with dirt banks three to six

feet high. A half-mile down-stream the banks disappeared, the stream bed became swampy and the heavy forest gave place to smaller, more bushy vegetation. A little farther down one comes to tide-water. To my surprise practically the same species occurred here as on similar creeks, two thousand miles inland, on tributaries of the Rio Madeira.

August 14 was our last collecting day at Pará and completed the trip as originally planned. We then had 167 species and 9169 specimens of Odonata. Captain Strohm returned home from Pará taking with him all zoölogical specimens and most of our field equipment. The photographic apparatus and supplies used on the trip were supplied by Captain Strohm, whose skill and experience in tropical photography is well evidenced by over three hundred negatives depicting various phases of our work and travel.

For me, the lure of Rio de Janeiro proved too strong to resist. I left Pará August 18 on the Lloyd Brazileiro SS. "Bahia," stopped for a few hours at Maranhão, Ceara, Pernambuco and Bahia en route and arrived in Rio de Janeiro on August 28. Sight-seeing and collecting were combined on numerous trips by auto, street-car or train into the surrounding country. Nearly all specimens collected were taken along streams in the vicinity of Alto Boa Vista on Mt. Tijuca at an estimated altitude of twelve to fifteen hundred feet. The Furnas road, at a point two kilometers beyond Alto Boa Vista, crossed a creek which had been badly polluted by laundry work and sewage. It was about one foot deep, varied in width from eight to twenty feet and had a rapid descent among boulders and outcroppings of solid rock. Working up-stream for a half mile to the first cascade, I found both exposed and well-shaded stretches. Down-stream the land on either side had been cleared and was under cultivation.

About ten minutes walk up the road leading to the right from the central plaza in Alto Boa Vista is a beautiful series of cascades on another stream. In the boulder-strewn creek bed below the falls, a Progomphus furnished rare sport during the brief periods of bright sunshine that occasionally penetrated the

clouds and foliage. Above the cascade the creek was easily followed for over a mile. Along one stretch where it paralleled the road the timber had been cut off. This was a favorite patrolling ground for a Coryphaeschna.

On September 7 I accompanied Dr. Boyd of the Rockefeller Commission on a field trip to Porto das Caixes on the Leopoldina Railroad northeast of Nichteroy. Swampy creeks near the town yielded a few specimens of Ceratura, Acanthagrion and Perithemis. Because of cloudy weather very few dragon-flies were on the wing. Fourteen species and 413 specimens were added to the collection at Rio de Janeiro. On October 5 I sailed on the Munson Line SS. "Western World" and landed in New York October 16.

In addition to the total of 9582 specimens representing 181 species of dragon-flies, 31 vials of spiders, 171 vials of ants, 50 cicadas, 150 reptiles and amphibians and a variety of miscellaneous insects were secured.

WEATHER CONDITIONS

At Pará, from December 30, 1921 to January 5, 1922, we had only one clear day. The rest were more or less cloudy with a heavy shower each afternoon. En route up the Amazon and Madeira rivers, from January 5 to 21, we encountered seven rainy days (including two days in port at Manáos), three cloudy, five partly cloudy and only two clear. At Porto Velho, from January 22 to March 5, we noted twenty-eight rainy days, seven cloudy, six partly cloudy and only two days entirely clear. At Abuná, from March 6 to 26, we had five days of rain, eight cloudy, six partly so and two clear. There were heavy showers on five days not classed as rainy. At Villa Murtinho, from March 28 to April 8, there were only two rainy days, with showers on two other days and rain during four nights. Four days were classed as cloudy, four partly so and two clear. During our six-day stop at Cashuela Esperanza, from April 10 to 15, we encountered one day of rain, three cloudy days and two partly so. There was scarcely an hour

during any day that local showers could not be seen up or down the river.

During our second stop at Porto Velho, from April 22 to May 29, we counted seven rainy days with showers on eight others, eight cloudy, thirteen partly cloudy and nine clear. Going down the Rio Madeira to Manáos, the last of May and first five days in June, we had three clear days and three generally cloudy, with showers. At Manáos, from June 6 to July 1, it rained most of three days and parts of eight others; the latter are included among three cloudy and eighteen partly cloudy days. Only one day was listed as clear. On the Rio Negro trip, from July 2 to 13, we had four cloudy days, five partly cloudy and one clear day. There were showers on three of the days listed as cloudy or partly so; at Manáos from July 13 to 22, there were two days of rain, two cloudy, three partly cloudy and three clear. Going down the Amazon from Manáos to Pará the latter part of July, we encountered one rainy day, three cloudy, two partly cloudy and one clear. At Pará, from July 30 to August 17, there were four days of rain, five cloudy, seven partly cloudy and four clear. During my visit in Rio de Janeiro from August 28 to October 4, no hard rains occurred. It sprinkled on only five days. Generally, however, the atmosphere was hazy over the city, with fleecy clouds around the mountain peaks nearby. I classified twenty days as hazy or cloudy, thirteen as partly so, and five as clear. From the tourist's viewpoint it was delightful weather, but nevertheless quite exasperating to a collector of dragon-flies which are active only on bright sunny days.

COST OF TRIP

My necessary travel and living expenses during the ten and one-half months away from home amounted to $1450. The Booth Line fare from New York to Pará was $165, but has been considerably reduced. Because of the depreciation of the milreis — normally a little over three to the dollar, but varying during our trip from 7160 to 8560 to the dollar — living expenses in Brazil were very cheap. Hotel rates throughout the

Amazon Valley varied from ten to fourteen milreis per day, including meals. The Amazon River Steam Navigation Company's fare, berth and meals included, from Pará to Manáos was 102$000 (102 milreis) or approximately $14 for a week's journey. Baggage rates and porterage, while expensive in Brazilian currency, were universally cheaper than in the United States. Railroad fare on the Madeira-Mamoré Railway at current exchange rate was about six cents per mile. Automobile rates varied from fifteen to twenty milreis per hour. The zone system was in use on all street car lines; the first class fare for each zone varied in different cities from 100 to 200 reis. To ride from the center of any city to the end of a car line some five or six miles out usually covered three zones and cost the equivalent of eight or ten cents.

In Rio de Janeiro advantage was taken of the crowds attending the opening ceremonies of the Centennial Exposition and the hotel rates were more than doubled. Even then living was cheaper than in our larger cities. By the time I left Rio de Janeiro hotels had lowered their prices practically to the normal rates.

It may be helpful to others who contemplate a similar trip to Brazil to state that, during the nine months spent on Brazilian soil, the necessary expenditures for one person amounted to 7000 milreis.

Sufficient funds were contributed by the University of Michigan, the Carnegie Museum, the Museum of Comparative Zoölogy, the Philadelphia Academy of Science, the Field Museum, Mr. E. B. Williamson and Mr. Wm. T. Davis to pay our travelling expenses to Pará, Brazil, and return. All expenditures in Brazil were met by the members of the expedition.

NOTES ON EQUIPMENT

We carried practically the same field equipment that was used on previous trips to Columbia, Venezuela and Peru.[1] In addition we took folding army cots, light-weight blankets and

[1] *A Collecting Trip to Columbia, South America*, E. B. Williamson, *Misc. Pub., Mus. of Zoölogy, Univ. of Mich.*, No. 3.

mosquito nets packed in the regulation army officer's bedding roll, which enabled us to stay comfortably at places where otherwise we could not have stopped. Since former experiences had demonstrated that large or odd-shaped trunks and chests frequently impeded travel in South America, we adopted the army locker trunk as a standard container. It is of proper dimensions to be packed two or three to each mule, depending on the gross weight of trunk and contents.

Heretofore the killing bottles have become "weak" or "dead" after continued use or accidental exposure to sun or water. Cleaning "dead" bottles and making new ones by using potassium cyanide, sawdust and plaster of Paris is not feasible in the field. Experiments to obviate this difficulty were tried with several chemical mixtures during the summer of 1921. As a result one dram vials, half filled with an equal mixture of pulverized potassium cyanide and citric acid and plugged with cotton, were inserted in the corks of the killing bottles. After being used for about two weeks, the vials were easily cleaned, refilled and ready for immediate use. Beetles and other specimens too large to pass through the necks of the killing bottles, were killed in used film-pack tins by the gases from one or two of such vials.

A friendly interest in our work and the utmost courtesy were manifested by all with whom we came in contact. Quite a number of interesting zoölogical specimens were donated from time to time to the Museum. Many friends and acquaintances in addition to those heretofore mentioned extended hospitality or gave us valuable advice and assistance which added greatly to the pleasure and effectiveness of our trip.

University of Michigan

RECORDS OF THE DISTRIBUTION OF MICHIGAN MAMMALS

NORMAN A. WOOD AND L. R. DICE

THE following records for the occurrence of various species of mammals in the State of Michigan have been collected over many years, mostly by the first author. The writing of the manuscript is mainly the work of the second author, with, however, much assistance from the first author.

Among the records given are many for species now extinct or rare in Michigan, and the information included in the paper is valuable chiefly for its bearing on the past distribution of the animals of the state. Recent records of specimens in the Museum of Zoölogy are in general not included, with the exception of rare forms. To the best of our knowledge none of the records here given have previously been published, although these records formed a part of the basis for N. A. Wood's *Annotated Check-List of Michigan Mammals*, published in 1914.

Specimens are available for very few of the records presented, but every effort has been made to have the specific identifications reliable. Numerous records about which there might be uncertainty as to the specific identifications have been omitted. In a few cases where two species might be confused, as in that of the flying squirrels, the records have been grouped together, with an indication of the species in those cases where this could be determined with certainty.

Many of the records have been furnished by various naturalists in the state; others have been secured from taxidermists, from hunters and trappers, and from farmers or other residents. For every record here included it is believed that the source has been entirely trustworthy. The persons named below have furnished the greater number of the records:

Dr. H. A. Atkins, naturalist, formerly residing at Loche, Ingham County (notes through T. L. Hankinson).

Dr. H. B. Baker, of the Department of Zoölogy, University of Pennsylvania.

Frank Baum, for twenty-two years a trapper in various parts of the Upper Peninsula of Michigan, mostly in Mackinac County.

Prof. W. B. Barrows, formerly of Michigan Agricultural College.

Prof. W. J. Beal, formerly of Michigan Agricultural College (notes through T. L. Hankinson).

E. E. Brewster, naturalist, formerly of Iron Mountain, Dickinson County.

W. A. Brotherton, naturalist, formerly of Rochester, Oakland County.

R. A. Brown, M.D., graduate of the University of Michigan.

J. Buchanan, farmer, of Big Creek, Oscoda County.

Kitson Cobb, game warden, of Portage Lake, Washtenaw County.

Prof. L. J. Cole, now at the University of Wisconsin.

A. B. Covert, formerly on the staff of the University of Michigan Museum.

John Driy, an old resident of Holland, Ottawa County.

C. K. Dodge, botanist, formerly of Port Huron.

A. B. Durfee, naturalist, formerly of Grand Rapids.

Dr. Morris Gibbs, naturalist, formerly of Kalamazoo.

Prof. T. L. Hankinson, of the Ypsilanti State Normal College.

Walter Hastings, ornithologist, now at South Lyon, Oakland County.

L. C. Hodges, resident near Stanton, Montcalm County.

Dr. Walter Koelz, of the U.S. Bureau of Fisheries.

Isaac Lamoex, an old resident of New Richmond, Allegan County.

Wm. McGraw, trapper, of Vermillion, Chippewa County, and of Two Hearted Life-saving Station, Luce County.

Albert Miller, old resident farmer, of Lewiston, Montmorency County.

T. Moore, an old hunter of Montague, Muskegon County.

E. L. MOSELEY, naturalist, now at State Normal College, Bowling Green, Ohio.

W. E. MULLIKEN, naturalist, formerly of Grand Rapids.

E. A. PURCHASE, old resident of Township 26 North, Range 1 West, Crawford County.

WALTER RODGER, an old hunter and trapper, now of Charlevoix, Charlevoix County.

PERCY SELOUS, naturalist, formerly of Greenville, Montcalm County.

C. F. SMITH, a resident of Forrestville, Sanilac County, from 1844 to 1877.

SAMUEL SPICER, a resident taxidermist in Goodrich, Genesee County, first arriving in the county in 1845.

DR. J. B. STEERE, formerly curator of the Museum, University of Michigan.

JOSEPH H. STEERE, a justice of the Michigan Supreme Court, living for many years at Sault Ste. Marie, Chippewa County.

ALBERT TERRILL, taxidermist, of Norway, Dickinson County.

CRYSTAL THOMPSON, formerly on the staff of the Museum of Zoölogy, University of Michigan.

JEROME TROMBLEY, naturalist, formerly of Petersburg, Monroe County.

ED. VAN WINKLE, naturalist, formerly of Van's Harbor, Delta County.

HON. L. D. WATKINS, formerly a resident of Manchester, Washtenaw County.

J. C. WEEKS, old resident of Napoleon, Jackson County.

W. C. WEEKS, old resident of Napoleon, Jackson County.

PROF. R. H. WOLCOTT, now of the Department of Zoölogy, University of Nebraska.

J. CLAIRE WOOD, naturalist, formerly of Detroit.

ORRIN J. WENZEL, formerly a student of the Department of Zoölogy, University of Michigan.

C. V. WOODIN, an old trapper of Republic, Marquette County.

Also a number of records of specimens in the museum of the Michigan Agricultural College have been reported to us by

W. B. Barrows; and N. A. Wood has examined a small collection of mammals belonging to the Edwardsburg High School, Cass County.

The records are arranged by species; under the species they are given by counties listed alphabetically.

Didelphis virginiana virginiana

Opossum

Allegan. — Isaac Lamoex reports that it occurred at New Richmond when he arrived there in 1845.

Cass. — Crystal Thompson in 1908 found it rare near Cassopolis.

Eaton. — In the collection of the Michigan Agricultural College is a specimen taken January, 1903, at Diamondale, and another taken in the same year at Grand Ledge.

Genesee. — Samuel Spicer reports one killed in Atlas Township in the fall of 1857, the only one he knows of being taken in the county. This is perhaps the same specimen reported by Miles in the first *Biennial Report of Progress of the* (Michigan) *Geological Survey.*

Gratiot. — W. B. Barrows has a record of one killed in the fall of 1905 in Washington Township.

Ingham. — E. R. Hawley, a resident, reports one taken in 1910 in Leslie Township, and another taken in 1906 in Bunker Hill Township. In the collection of the Michigan Agricultural College is a specimen taken March 29, 1899, at Holt.

Isabella. — W. B. Barrows has a record of one taken in the summer of 1898 or 1899 at Shepherd.

Monroe. — Jerome Trombley in 1910 reported it to have been "not uncommon" near Petersburg about 1850, but none had been noted since 1865.

Oakland. — John Bassett, a resident, caught one in 1850 in his orchard near Novi.

Ottawa. — W. B. Barrows reports one taken in 1911 near Ottawa.

Wayne. — J. Claire Wood saw one trapped near Trenton, De-

cember 1, 1900; he heard of three others being taken during February, 1904, near the same place. A. B. Durfee in 1898 reported it found in some numbers in the county.

Scalopus aquaticus machrinus

Prairie Mole

Cass. — Crystal Thompson found it common in 1911 near Cassopolis.

Genesee. — Samuel Spicer in 1910 reported it common in Atlas Township.

Kent. — R. H. Wolcott in 1898 reported it common at Grand Rapids.

Monroe. — Jerome Trombley in 1910 reported it abundant at Petersburg.

Montcalm. — Percy Selous in 1898 reported it common near Greenville.

Oscoda. — N. A. Wood saw a few ridges in the sandy plains near Butler Bridge in 1903.

Ottawa. — H. Imus, a resident, in 1910 reported it common near Holland.

Van Buren. — A specimen taken in August, 1913, near Bangor is in the Edwardsburg High School.

Condylura cristata

Star-nosed Mole

Berrien. — Reported by H. D. Gross, a teacher, common in 1906–1907 near St. Joseph.

Chippewa. — Joseph H. Steere of Sault Ste. Marie wrote in 1910 that one had been brought him by a boy.

Genesee. — Samuel Spicer reported it common in Atlas Township, but in 1910 he had not seen any since 1902.

Ingham. — T. L. Hankinson reports one taken at Lansing in 1897.

Jackson. — W. C. Weeks caught several near Napoleon in 1902.

KALAMAZOO. — The Museum of Zoölogy has a specimen taken by Morris Gibbs in the county.

KENT. — In 1898 R. H. Wolcott reported it not rare at Grand Rapids; he took two in a cellar.

OAKLAND. — In 1910 W. A. Brotherton reported it common near Rochester. January 27, 1921, W. Hastings took a specimen in a greenhouse at South Lyon.

OSCODA. — N. A. Wood found one dead near Butler Springs in July, 1903.

SHIAWASSE. — In 1898 A. B. Durfee reported he had taken specimens in the county.

SOREX PERSONATUS PERSONATUS

Masked Shrew

CHEBOYGAN. — N. A. Wood took a specimen July 10, 1914, at Douglas Lake.

ONTONAGON. — The specimen taken August 2, 1904 in the Porcupine Mountains and recorded as *Sorex hoyi* (*Mich. Geol. Surv., Rept.*, 1905, p. 130) proves to be this species.

BLARINA BREVICAUDA TALPOIDES

Bob-tailed Shrew

INGHAM. — T. L. Hankinson in 1898 reported it very common at East Lansing.

KENT. — W. E. MULLIKEN in 1898 reported it to occur near Grand Rapids.

WAYNE. — J. C. Wood in 1910 reported it common near Detroit.

CRYPTOTIS PARVA

Small Shrew

INGHAM. — H. A. Atkins reports that he took one in 1874, probably at that place.

JACKSON. — A female in the collection of Walter Koelz was taken near the Washtenaw County line May 27, 1922, by Donald Savery.

Myotis lucifugus lucifugus.

Little Brown Bat

Arenac. — The specimens from the Charity Islands listed as *Myotis subulatus* (*Mich. Acad. Sci., 13th Rept.*, 1911, p. 134) prove to be *M. l. lucifugus.*

Ontonagon. — Walter Koelz took a specimen August 27, 1921, at the mouth of Iron River.

Myotis subulatus subulatus

Say Bat

Ontonagon. — August 27, 1921, Walter Koelz took a specimen at the mouth of Iron River.

Lasionycteris noctivagans

Silver-haired Bat

Ingham. — A specimen taken August 8, 1895, at East Lansing, is in the collection of the Michigan Agricultural College.

Eptesicus fuscus fuscus

Brown Bat

Van Buren. — A specimen in the Edwardsburg High School was taken May 5, 1910, at South Haven.

Nycteris borealis borealis

Red Bat

Dickinson. — E. E. Brewster in 1898 reported it numerous near Iron Mountain; it was often found hibernating with Myotis in old mine tunnels.

Kalamazoo. — The Museum of Zoölogy has a specimen taken by Gibbs in 1875 at Kalamazoo.

Kent. — R. H. Wolcott and L. J. Cole in 1898 reported it common around lights at Grand Rapids; the latter took eight in one evening with a net.

Monroe. — Jerome Trombley in 1910 reported it occasionally found near Petersburg.

Nycteris cinerea

Hoary Bat

Dickinson. — Michigan Agricultural College has a specimen taken by E. E. Brewster in 1897 at Iron Mountain.

Kent. — R. H. Wolcott in 1898 reported it uncommon at Grand Rapids.

Montcalm. — Michigan Agricultural College has a specimen taken at Greenville. Percy Selous in 1898 reported it not rare at Greenville; in the summer of 1897 he secured a photograph of a female with young attached to her breast.

Wayne. — J. Claire Wood in 1897 found several in Woodland Lawn Cemetery.

Ursus americanus americanus

Black Bear

Allegan. — It occurred near New Richmond when Isaac Lamoex arrived there in 1845.

Crawford. — In 1903 residents reported to N. A. Wood that it was common in the county.

Dickinson. — A. G. Ruthven and F. M. Gaige saw one at Brown Lake in the summer of 1909.

Genesee. — Samuel Spicer reports one killed in Atlas Township about 1858 or 1860 and another about 1867 or 1868.

Gladwin. — Wesley Bradfield, a forester, reported one from Tobacco Township in the fall of 1897.

Grand Traverse. — W. E. Hastings saw one in summer, about 1900, in Long Lake Township.

Ingham. — W. J. Beal stated in 1895 that one was killed about 1878 near the site of the present Harrison Hall, East Lansing. H. A. Atkins reports one killed in the county in 1883.

Jackson. — John C. Weeks in 1842 shot one near Napoleon.

Kalamazoo. — Morris Gibbs reports that the last one killed in the county was taken December 15, 1885.

KENT. — L. J. Cole in 1898 stated that it had occurred near Grand Rapids until within comparatively recent times. Kent Scientific Institute has a female and cub taken many years ago at Grand Rapids.

LIVINGSTON. — L. C. Palmer, formerly of Dexter, reports one killed in 1867 near Howell.

LUCE. — In 1914 residents reported to N. A. Wood that it was common in the county. John Clark, a resident, reports a female with four cubs taken in 1913 on Two Hearted River.

MACKINAC. — Frank Baum and his brother report killing thirty-one in the county during the winter of 1894–1895.

MISSAUKEE. — Percy Selous in 1898 reported it common in the county.

MONROE. — Jerome Trombley reports it common prior to 1820 in the dense forests near Petersburg; his father killed a large female with two cubs in 1843, the last ones known to have occurred in the region.

MONTCALM. — Percy Selous reports one killed near Greenville in the winter of 1896.

MONTMORENCY. — Albert Miller in 1910 reported it still common near Lewiston.

OAKLAND. — Wm. Duncan, a farmer and hunter, states that in 1842 he killed the last one seen in the county.

OSCODA. — J. Buchanan, in April, 1903, shot one near Big Creek.

ROSCOMMON. — Wesley Bradfield, a forester, reported one killed in September, 1903, near Houghton Lake.

SCHOOLCRAFT. — E. N. Woodcock caught four in the winter of 1875–1876 at the headwaters of the Manistique River.

SHIAWASSEE. — T. L. Hankinson reports a female with cubs taken in 1897 near Corunna.

CANIS LYCAON

Timber Wolf

ALLEGAN. — Was found near New Richmond when Isaac Lamoex arrived there in 1845.

Cheboygan. — Addison Doolittle, a hunter, killed one near Black River in 1882.

Genesee. — Samuel Spicer reports that none occurred in Atlas Township after 1845, but it had been seen shortly before that time.

Ingham. — T. L. Hankinson in 1898 stated that it had long been extinct in the county.

Jackson. — John C. Weeks killed one near Napoleon in 1840.

Mackinac. — J. Claire Wood found them unusually abundant in the county in 1890. Frank Baum and brother caught eleven in the county during the winter of 1894–1895.

Monroe. — Jerome Trombley reported it abundant near Petersburg until 1820; by 1850 it had entirely disappeared.

Oscoda. — In 1903 residents reported to N. A. Wood that it was rare in the county.

Sanilac. — C. F. Smith, a resident at Forrestville from 1844 to 1877, states it was never very common during that time.

Schoolcraft. — E. N. Woodcock caught five in the winter of 1875–1876 at the headwaters of the Manistique River. J. E. Richie killed two in 1912 and one in 1914 near Floodwood.

Tuscola. — Samuel Spicer in 1863 saw tracks of two in the lumber woods of the county.

Canis latrans

Brush Wolf, Coyote

Alger. — In a taxidermy shop at Sault Ste. Marie, N. A. Wood saw one which had been taken in March, 1912, near Munising.

Berrien. — W.. B. Barrows has a record of two wolves, probably this species, killed near New Buffalo in the winter of 1900–1901 or the previous year. The wolves reported from Berrien County by Dice (1920, *Occ. Papers Mus. Zoöl. Univ. Mich.*, No. 86, pp. 17–18) were probably this species also.

Dickinson. — February 25, 1912, one was poisoned near Norway by a farmer and taken to Albert Terrill to be mounted.

GENESEE. — The Museum of Zoölogy has a specimen taken March 26, 1917, in Fenton Township.

MARQUETTE. — C. V. Woodin in 1913 reported a few brush wolves in the county.

MENOMINEE. — Frank Baum in 1911 stated that he had trapped in nearly all the counties in the Northern Peninsula, but found coyotes only in this one.

SCHOOLCRAFT. — J. E. Richie, a trapper, in 1915 reported it not rare near Floodwood.

VULPES FULVA

Red Fox

ALLEGAN. — Isaac Lamoex in 1914 reported it to occur at New Richmond.

ANTRIM. — Reported by W. E. Hastings common in 1908 in the county.

DICKINSON. — E. E. Brewster in 1898 reported it rather common at Iron Mountain. In 1909 A. G. Ruthven saw many fresh skins at Norway and residents reported it common in the county.

GENESEE. — H. B. Baker in 1905 reported it rare at Flint.

GRAND TRAVERSE. — Reported by W. E. Hastings in 1920 to be common in the county.

INGHAM. — T. L. Hankinson wrote in 1898 that it was still found in the county.

KALKASKA. — A. B. Covert reports a silver gray taken at Sand Lake in 1882.

KENT. — In 1898 the resident naturalists reported it numerous near Grand Rapids.

LIVINGSTON. — N. A. Wood in 1905 saw one near Portage Lake.

LUCE. — Wm. McGraw in 1908 shot two at Two Hearted Station and reported it common.

MACKINAC. — Frank Baum and brother trapped it in the county during the winter of 1894–95.

MONROE. — Jerome Trombley in 1910 reported it as not known

near Petersburg in the early pioneer days; it was first noted about 1855, and it has never been common.

MONTCALM. — Percy Selous in 1898 reported it less common than formerly near Greenville.

MONTMORENCY. — Albert Miller in 1911 reported it common near Lewiston.

OAKLAND. — W. E. Hastings in 1920 saw two whelps in Orion Township and reported it common in Rose Township.

OSCODA. — N. A. Wood saw one in July, 1903, near Butler Bridge, and at that time residents reported it common in the county.

OTTAWA. — John Driy in 1906 reported it rare; one was shot in the fall of that year near Holland.

WAYNE. — J. Claire Wood in 1910 reported that there were about five dens of the species in the county.

UROCYON CINEREOARGENTEUS CINEREOARGENTEUS

Gray Fox

ALLEGAN. — Isaac Lamoex in 1914 reported it to occur near New Richmond.

ANTRIM. — W. E. Hastings took one in this county in 1909, and reported it numerous, but formerly more common.

BAY. — W. B. Barrows has a record of one killed in January, 1908, near Bentley.

CHARLEVOIX. — Walter Rodger in 1907 saw a fresh skin taken near Charlevoix.

CRAWFORD. — E. A. Purchase in 1903 reported it rare in Township 26 N., Range 1 W.

GRAND TRAVERSE. — W. E. Hastings reported it numerous in 1908 in the county.

JACKSON. — W. C. Weeks in November, 1860, shot one near Napoleon.

MONROE. — Jerome Trombley reported it not uncommon near Petersburg before 1850; it began to disappear with the advent of the red fox, and in 1910 was probably extinct in the region.

MONTCALM. — Percy Selous in 1898 reported it formerly common, but then rare near Greenville.

MONTMORENCY. — Albert Miller in 1911 reported it not rare near Lewiston.

OSCODA. — J. Buchanan in 1903 reported it rare near Big Creek.

WEXFORD. — A. B. Covert in the winter of 1881–1882 bought several skins from trappers operating near Cadillac.

PROCYON LOTOR LOTOR

Raccoon

ALLEGAN. — Was found near New Richmond in 1845 when Isaac Lamoex arrived there.

ANTRIM. — W. E. Hastings reported it fairly abundant in suitable places in 1914 in the county.

DICKINSON. — E. E. Brewster in 1898 reported it occasionally taken near Iron Mountain.

GRAND TRAVERSE. — W. E. Hastings reported it common in the county in 1908.

INGHAM. — T. L. Hankinson wrote in 1898 that it was common in the county.

KENT. — Resident naturalists in 1898 reported it common near Grand Rapids.

LIVINGSTON. — Kitson Cobb in November, 1910, caught several near Portage Lake.

LUCE. — Wm. McGraw in 1906 trapped six near Two Hearted Station.

MONROE. — Jerome Trombley reports it to have been common near Petersburg between 1870 and 1885, but in 1910 it occurred only in limited numbers, becoming scarcer every year.

MONTCALM. — Percy Selous in 1898 reported it common near Greenville

OAKLAND — W. E. Hastings in 1920 saw one, and reported it fairly abundant in suitable places.

OSCODA. — In 1903 residents reported to N. A. Wood that it was numerous in the county.

PRESQUE ISLE. — In October, 1882, N. A. Wood saw one which had been killed near Black Lake.

SCHOOLCRAFT. — E. N. Woodcock reports that it was plentiful in the winter of 1875–1876 at the headwaters of the Manistique River.

WAYNE. — J. Claire Wood in 1910 reported it not uncommon in the county; he found a number in Woodland Lawn Cemetery in 1897.

MARTES AMERICANA AMERICANA

Marten

ALGER. — In February, 1911, Fred Hawkins of Vermilion shot one near Grand Marias. George Shiras, 3rd, in 1916 reported it rare near Whitefish Lake, though it was formerly common.

ALLEGAN. — Isaac Lamoex reports it was found at New Richmond when he arrived there in 1845.

ALPENA. — E. N. Woodcock reports it was plentiful in the county when he trapped there in the winter, about 1867–1868.

CRAWFORD. — In 1903 residents reported to N. A. Wood that it was numerous in the county.

DELTA. — The Museum of Zoölogy has a mounted specimen taken in the county in February, 1893.

DICKINSON. — James Brush, a trapper, told A. G. Ruthven in 1909 that it was rare in the region.

GRAND TRAVERSE. — Reported by W. E. Hastings to have occurred formerly in the county.

LUCE. — In 1912 trappers in the northeastern part of the county reported to N. A. Wood that a few occurred in the forests.

MISSAUKEE. — Percy Selous in 1898 reported that it was common in the county.

MONTMORENCY. — Albert Miller in 1911 reported it rare near Lewiston.

PRESQUE ISLE. — The Museum of Zoölogy has a mounted specimen taken in December, 1883, at Black Lake.

SCHOOLCRAFT. — E. N. Woodcock reports it was very common in the winter of 1875–1876 at the headwaters of the Manistique River.

WEXFORD. — A. B. Covert bought many skins at Cadillac in 1881–1882; he reports it common there at that time.

MARTES PENNANTI PENNANTI

Fisher

ALGER. — E. N. Woodcock reports that it was common in the winter of 1875–1876. Between 1909 and 1916 several trappers reported it rare in the county.

ALPENA. — E. N. Woodcock reports that a few were found in the county in the winter of about 1867–1868.

HOUGHTON. — John Gordon, of Saline, Michigan, shot one in the fall of 1910 and another in November, 1911, near Allston. N. A. Wood has seen a male taken in the county in November, 1914; it weighed 12 pounds.

INGHAM. — H. A. Atkins reports a male weighing 20 pounds taken in the county in 1882.

LUCE. — In 1912 trappers in the northeastern part of the county reported to N. A. Wood that a few occurred there.

MISSAUKEE. — Percy Selous in 1898 stated it had been taken in the county.

MONTMORENCY. — Albert Miller in 1911 reported it rare near Lewiston.

PRESQUE ISLE. — Walter Rodger reports one killed near Black Lake in 1889.

SCHOOLCRAFT. — E. N. Woodcock reports that it was common in the winter of 1875–1876 at the headwaters of the Manistique River.

WAYNE. — A. B. Durfee reports two specimens caught in the county in 1830.

WEXFORD. — A. B. Covert in 1881–1882 bought the skins of several taken near Cadillac.

MUSTELA NOVEBORACENSIS NOVEBORACENSIS

New York Weasel

ALLEGAN. — In 1914 Isaac Lamoex reported weasels to occur near New Richmond.

ANTRIM. — W. E. Hastings reported weasels common from 1908–1914 in the county.

CASS. — In 1911 Crystal Thompson found weasels common near Cassopolis.

GRAND TRAVERSE. — W. E. Hastings reported weasels common in 1908 in the county.

INGHAM. — In the winter of 1897–1898 T. L. Hankinson took four in the county.

JACKSON. — In 1910 W. C. Weeks reported weasels common near Napoleon.

KENT. — In 1898 R. H. Wolcott and W. E. Milliken reported it common at Grand Rapids.

MONROE. — In 1910 Jerome Trombley reported it found sparingly near Petersburg, though it had been common in years past.

MONTCALM. — In 1898 Percy Selous reported it common near Greenville. In 1911 L. C. Hodges reported weasels common near Stanton.

MONTMORENCY. — In 1911 Albert Miller reported weasels common near Lewiston.

OTTAWA. — In 1907 John Driy reported weasels not common near Holland.

VAN BUREN. — N. A. Wood has seen a specimen in the Edwardsburg High School Collection, which was taken May 5, 1910, near South Haven.

WAYNE. — In 1910 J. Claire Wood reported it rather common in the county.

MUSTELA VISON LETIFERA

MUSTELA VISON MINK

Mink

ALLEGAN. — It was found near New Richmond when Isaac Lamoex arrived there, and still occurs.

CHARLEVOIX. — In 1910 Walter Rodger reported it common in the county.

CHEBOYGAN. — In the fall of 1883 N. A. Wood shot one and trapped another on Black River.

CRAWFORD. — In 1903 residents reported to N. A. Wood that it was common.

GENESEE. — In 1905 H. B. Baker reported it common near Flint. Samuel Spicer in 1910 reported that it has always been common in Atlas Township.

GRAND TRAVERSE. — W. E. Hastings reported it common in the county up to 1920.

INGHAM. — In 1898 T. L. Hankinson and L. J. Cole reported it common in the county.

IONIA. — In 1898 L. J. Cole reported it common in the county.

JACKSON. — In 1910 W. C. Weeks reported it common near Napoleon.

KENT. — In 1898 several resident naturalists reported it common near Grand Rapids.

LUCE. — In 1907 Wm. McGraw caught seven near Two Hearted Station.

MONROE. — In 1910 Jerome Trombley reported it growing scarcer near Petersburg, where it was common until 1885.

MONTCALM. — In 1898 Percy Selous reported it common near Greenville.

OSCODA. — In July, 1903, N. A. Wood saw one in Big Creek; at that time residents reported it common in the county.

OTTAWA. — In 1898 L. J. Cole reported it common in the county.

SCHOOLCRAFT. — E. N. Woodcock reports that it was very common and many were caught in the winter of 1875–1876 at the headwaters of the Manistique River.

WAYNE. — In 1910 J. Claire Wood reported it rather common in the county.

GULO LUSCUS

Wolverine

CHIPPEWA. — Joseph H. Steere writes that he has seen a mounted specimen said to have been killed in this county before 1880 by an old Indian; that was said to be the last one taken near Sault Ste. Marie. He has also heard it said that long ago, in the days of the old fur companies, wolverine skins were occasionally purchased from the Michigan Indians.

Kent. — R. H. Wolcott wrote in 1898 that he had seen specimens taken by sportsmen to the north of Grand Rapids. He does not now remember from how great a distance these specimens came.

Oscoda. — L. D. Watkins states that in 1844 he shot one while he was hunting in a big swamp along the lower Au Sable River; at that time they were occasionally found in the Southern Peninsula, but they were not fond of sparsely timbered lands.

Schoolcraft. — E. N. Woodcock, a trapper, was much bothered by a wolverine in the winter of 1875–1876 at the headwaters of the Manistique River. He set traps and caught the animal, and later he saw tracks of others.

Mephitis hudsonica

Northern Plains Skunk

Dickinson. — In 1898 E. E. Brewster reported it common at Iron Mountain.

Luce. — Between 1900 and 1908 Wm. McGraw trapped numbers of them at Two Hearted Station.

Mephitis nigra

Eastern Skunk

Antrim. — W. E. Hastings reports it common up to 1920 in the county.

Cass. — In 1911 Crystal Thompson found it common near Cassopolis.

Crawford. — In July, 1903, N. A. Wood saw one at Big Creek; at that time residents reported it common in the county.

Grand Traverse. — W. E. Hastings reports it common until 1920 in the county.

Ingham. — In 1898 T. L. Hankinson reported it common in that county.

Kent. — In 1898 R. H. Wolcott and W. E. Milliken reported it common near Grand Rapids.

Monroe. — In 1910 Jerome Trombley reported it still quite prevalent near Petersburg, where it was formerly much more common.

Montcalm. — In 1898 Percy Selous reported it very common near Greenville.

Oakland. — In 1921 W. E. Hastings reported it common near South Lyon.

Oscoda. — In 1903 various residents reported to N. A. Wood that it was common in the county.

Wayne. — In 1910 J. Claire Wood reported it rather common in the county.

Taxidea taxus taxus

Badger

Alger. — In November, 1913, one was trapped by James O. Cooper, a trapper, near Grand Marias.

Cass. — In 1911 Crystal Thompson found it rare near Cassopolis.

Charlevoix. — Walter Rodger reports one caught in 1910 at Charlevoix.

Crawford. — In 1903 residents reported to N. A. Wood that it was common in the county.

Dickinson. — E. E. Brewster reports one killed in 1893 and another in 1895 at Iron Mountain. In 1913 C. V. Woodin reported it to occur on the sandy wastes of the northern part of the county.

Genesee. — In the winter of 1889 Samuel Spicer caught one in Atlas Township. February 1, 1903, one was killed on the farm of Frank Harris in Grand Blanc Township.

Hillsdale. — T. L. Hankinson reports a few taken in the county about 1890.

Ingham. — A mounted specimen taken at Lansing is in the collection of the Michigan Agricultural College.

Ionia. — In 1863 J. B. Steere killed a large one and dug out two young at Belding.

Jackson. — In 1900 W. C. Weeks killed one at Columbia.

KALAMAZOO. — Morris Gibbs reports one captured May 14, 1877, at Kalamazoo.

KENT. — In 1898 R. H. Wolcott and W. E. Milliken reported it occasionally found near Grand Rapids.

LENAWEE. — Asa Kogle, a farmer, killed one near Morenci March 22, 1906.

MONROE. — Jerome Trombley reports one killed about 1892 near Petersburg.

MONTCALM. — Percy Selous reports three taken by him previous to 1898 near Greenville.

MONTMORENCY. — In 1911 Albert Miller reported it common near Lewiston.

OAKLAND. — In 1911 W. A. Brotherton reported it quite common near Rochester. W. E. Hastings has records for near South Lyon about 1916 and about 1919.

OSCODA. — July 11, 1903, N. A. Wood saw tracks and a freshly dug hole near Butler Bridge. In 1915 James Buchanan reported it common at Big Creek.

PRESQUE ISLE. — N. A. Wood has seen the skin of one taken October, 1883, near Black Lake.

WASHTENAW. — In February, 1923, Will Haynes, a hunter of Ann Arbor, saw where a badger had dug out six woodchuck dens south of the city. The tracks were very plain in the snow and sand.

WAYNE. — In 1898 A. B. Durfee reported that some occur in the county.

LUTRA CANADENSIS CANADENSIS

Otter

ALLEGAN. — It occurred near New Richmond when Isaac Lamoex arrived there in 1845.

BRANCH. — In 1916 Albert Keel, a farmer, saw one in Ovid Township.

CHIPPEWA. — In 1912, in a taxidermy shop, N. A. Wood saw a skin which had been taken near Sault Ste. Marie.

CRAWFORD. — In 1903 residents reported to N. A. Wood that it was common in the county.

DICKINSON. — In 1898 E. E. Brewster reported having seen it near Iron Mountain. Albert Terrill reports one taken in 1908 near Norway.

GENESEE. — Samuel Spicer reports one killed in Atlas Township about 1866; he used to see signs frequently along Kearsley Creek.

GRAND TRAVERSE. — W. E. Hastings reports that in 1905 it was rare and in 1920 very rare in the county.

INGHAM. — T. L. Hankinson reports that in 1887 a resident saw one in Grand River in Lansing.

IRON. — In July, 1902, J. H. Bortle, of Birmingham, saw a family of four on Paint River near Crystal Falls.

KENT. — In 1898 R. H. Wolcott reported it rare near Grand Rapids.

LIVINGSTON — W. E. Hastings has a record of one seen in 1920 by a resident in Green Oak Township.

MACKINAC. — In the winter of 1894–1895 Frank Baum and brother trapped them in the county.

MONROE. — Jerome Trombley reports it not uncommon along the River Raisin during the early part of the nineteenth century; his father shot one in 1844, the last record for the river which is known to him.

MONTCALM. — In 1898 Percy Selous reported it rare near Greenville, though it was formerly common.

OSCODA. — In 1903 residents reported to N. A. Wood that it was common in the county.

WEXFORD. — In 1881–1882 A. B. Covert bought several skins taken near Cadillac; in the fall of 1881 he saw a slide on Clam River.

FELIS COUGUAR

Cougar, Panther

ALLEGAN. — Isaac Lamoex knows of but one being found near New Richmond since he arrived there in 1845.

INGHAM. — L. C. Hodges has seen a mounted specimen which was taken at Pleasant Lake in 1875.

MONTCALM. — L. C. Hodges reports his dogs treed one near Stanton in 1885, but he did not have a gun and lost the animal.

LYNX CANADENSIS CANADENSIS

Canada Lynx

There is considerable possibility that the Canada lynx and the bob-cat are confused in some of the records here included under the two species.

ALLEGAN. — It was found at New Richmond when Isaac Lamoex arrived there in 1845.

CHIPPEWA. — In 1910 Joseph H. Steere reported it as still occurring near Sault Ste. Marie, where it was formerly more numerous than the bob-cat. N. A. Wood in a taxidermy shop at Sault Ste. Marie saw a specimen killed not far from there in August, 1912. Michigan Agricultural College has a specimen taken March 1, 1900, at Rudyard.

CRAWFORD. — In 1903 E. A. Purchase reported it rare in the eastern part of the county.

MACKINAC. — In the winter of 1894–1895 Frank Baum and brother killed thirty-four in the county.

MONROE. — Jerome Trombley reports one taken near Petersburg in 1842, the last one of which he heard in that region; it was common in the early days.

MONTCALM. — In 1910 L. C. Hodges reported it still present near Stanton.

OSCODA. — In February, 1903, J. Buchanan trapped one at Big Creek. In 1844 L. D. Watkins killed one in a big swamp along the lower Au Sable River.

SCHOOLCRAFT. — E. N. Woodcock reports that he caught several in the winter of 1875–1876 at the headwaters of the Manistique River.

WEXFORD. — Percy Selous reports one taken in November, 1894, 18 miles east of Cadillac.

LYNX RUFFUS RUFFUS

Bob-cat

ALLEGAN. — It occurred near New Richmond when Isaac Lamoex arrived there in 1845.

Antrim. — W. E. Hastings reports wild-cats of some species fairly common and often seen in 1914 in this county.

Crawford. — In 1903 residents reported to N. A. Wood that it was common in the county.

Dickinson. — A. G. Ruthven has seen a skin taken near Pine Creek in 1909.

Huron. — The Museum of Zoölogy has a mounted specimen taken in 1879 at Bayport.

Grand Traverse. — W. E. Hastings reports wild-cats of some species formerly common, but rare in 1908 in this county.

Ingham. — H. A. Atkins reports it present when the county was new.

Luce. — In 1907, at Two Hearted Station, Wm. McGraw saw three, of which two were killed.

Mackinac. — Frank Baum and brother caught five in the county in the winter of 1894–1895.

Monroe. — Jerome Trombley reports it was common near Petersburg about 1885; in 1910 probably none occurred in the region.

Montcalm. — Percy Selous reports a male killed near Greenville January 9, 1894.

Oakland. — The Museum of Zoölogy has a mounted specimen taken in 1869 at Rochester.

Oscoda. — In 1903 J. Buchanan reported it rare at Big Creek.

Wayne. — W. H. Brotherton reports that one was known to have lived in a big swamp near Royal Oak as late as 1910.

Wexford. — The Museum of Zoölogy has a mounted specimen taken in 1892 at Cadillac.

Peromyscus maniculatus bairdii

Prairie Deer Mouse

Cass. — In July, 1910, Crystal Thompson collected specimens at Cassopolis in fields near marshes and tamarack swamps.

Peromyscus leucopus noveboracensis

Northern Deer Mouse

Allegan. — In 1898 L. J. Cole reported it common in the county.

GENESEE. — In 1905 H. B. Baker reported it common near Flint.

INGHAM. — In 1898 T. L. Hankinson and L. J. Cole reported it common at East Lansing.

JACKSON. — In September, 1880, N. A. Wood found it common near Napoleon.

KALAMAZOO. — A specimen taken by Morris Gibbs is in the Museum of Zoölogy.

KENT. — In 1898 L. J. Cole and W. E. Mulliken reported it common at Grand Rapids.

LENAWEE. — In 1910 N. A. Wood found it common near Milan.

LIVINGSTON. — In 1910 N. A. Wood found it common at Lakeland.

MONTCALM. — In 1898 Percy Selous reported it common near Greenville.

OAKLAND. — In 1896 N. A. Wood found it common at South Lyon.

OTTAWA. — In 1898 L. J. Cole reported it common in the county.

WAYNE. — In 1910 J. Claire Wood reported it common near Detroit.

EVOTOMYS GAPPERI GAPPERI

Red-backed Vole

LUCE. — In August, 1914, N. A. Wood saw one which had been taken at Crisp Point.

SYNAPTOMYS COOPERI

Cooper Lemming-Vole

CASS. — The Museum of Zoölogy has several specimens taken in January, 1911 under a stack of corn stalks near Cassopolis.

MICROTUS PENNSYLVANICUS PENNSYLVANICUS

Pennsylvania Vole

CRAWFORD. — In 1903 residents reported to N. A. Wood that it was common in the county.

GENESEE. — In 1905 H. B. Baker reported it common near Flint.

INGHAM. — In 1898 T. L. Hankinson reported it common near East Lansing.

LENAWEE. — In 1901 N. A. Wood found it common near Milan.

LIVINGSTON. — In 1910 N. A. Wood found it common near Lakeland.

MONROE. — In 1910 Jerome Trombley reported it very common in meadows and grain fields near Petersburg; in autumn many are found under corn shocks, making their nests of corn leaves and fur. It is the common prey of the marsh hawk.

MONTCALM. — In 1898 Percy Selous reported it common near Greenville, being extensively preyed upon by hawks and owls and massaugas (rattlesnakes).

OAKLAND. — In 1881 N. A. Wood found it common near South Lyon.

VAN BUREN. — A specimen from near Bangor taken in 1913 is in the Edwardsburg High School.

WAYNE. — In 1910 J. Claire Wood reported it common near Detroit.

ONDATRA ZIBETHICA ZIBETHICA

Muskrat

GENESEE. — Samuel Spicer in 1910 reported it common in Atlas Township; he caught many between 1860 and 1870.

GRAND TRAVERSE. — W. E. Hastings reports it formerly common, but much reduced in 1905 in this county.

INGHAM. — In 1898 T. L. Hankinson and L. J. Cole reported it common in the county.

IONIA. — In 1898 L. J. Cole reported it common in the county.

KENT. — In 1898 several resident naturalists reported it common at Grand Rapids.

LUCE. — In August, 1912, Orrin J. Wenzel found it not rare along the Taquamenaw River.

MONROE. — Jerome Trombley reports that it once swarmed in the River Raisin and its tributaries and adjacent ponds;

in 1890 it was still quite common; but in 1910 only a few were left near Petersburg, although at that time they were still found in considerable numbers on the Monroe Marshes at the mouth of the Raisin.

MONTCALM. — In 1898 Percy Selous reported it very common in the county.

MUSKEGON. — In 1910 T. Moore reported it common near Montague.

OTTAWA. — In 1908 John Driy reported it very common near Holland.

PRESQUE ISLE. — In 1883 N. A. Wood found it common at Black Lake.

WASHTENAW. — In the early winter of about 1912 a muskrat was killed beside a house in the midst of the city of Ann Arbor, over a mile from the nearest stream. N. A. Wood saw the specimen.

WAYNE. — In 1910 J. Claire Wood reported it tolerably common in the county.

RATTUS NORVEGICUS

Brown Rat

INGHAM. — H. A. Atkins states that it was not found at Loche until after the country had been settled about twenty years.

ZAPUS HUDSONIUS HUDSONIUS

Hudson Bay Jumping-Mouse

ALGER. — A specimen in the collection of the Michigan Agricultural College was taken in August, 1900, at Chatam.

KALAMAZOO. — Prof. Wm. Praeger of Kalamazoo College reports one taken near Kalamazoo in 1910.

KEWEENAW. — In August, 1907, A. C. Lane, Director of the State Geological Survey, found one drowned in a water bucket at Mandan.

WAYNE. — A. B. Durfee in 1898 reported it quite plentiful in the county.

Erethizon dorsatum dorsatum

Porcupine

Alcona. — September 20, 1903, N. A. Wood saw several near Bamfield.

Allegan. — In 1914 Isaac Lamoex reported it to occur at New Richmond.

Antrim. — W. E. Hastings reports it fairly common and often seen up to 1914 in this county.

Cass. — E. E. Thompson, an old resident, reports it as present in the county in 1850.

Crawford. — In 1903 residents reported to N. A. Wood that it was common in the county.

Delta. — In 1895 Edward Van Winkle reported it common at Van's Harbor.

Dickinson. — In 1898 E. E. Brewster reported it common near Iron Mountain. A. G. Ruthven in 1909 saw a number at Brown Lake.

Genesee. — Samuel Spicer shot a large one about 1855 in Atlas Township.

Grand Traverse. — W. E. Hastings reports it common up to 1905 in this county.

Huron. — In 1908 an expedition of the Museum of Zoölogy found it rare on Sand Point; only one was seen during the summer, but several had been killed by woodcutters the previous winter.

Ingham. — Michigan Agricultural College has a specimen taken in 1869 at Lansing. T. L. Hankinson states that old residents report it once common in the county.

Iron. — In May, 1902, J. H. Bortle, of Birmingham, saw thirty-five in two days near Crystal Falls.

Kent. — In 1898 W. E. Mulliken reported it fast becoming extinct at Grand Rapids, where it was once common.

Jackson. — W. C. Weeks reports one killed in 1856 near Napoleon. E. R. Hawley, a resident, states that the last one to his knowledge in Waterloo Township was killed in 1869.

LUCE. — In August, 1912, Orrin J. Wenzel saw several along the Taquamenaw River. In August, 1914, N. A. Wood saw five in the northeastern part of the county.

MACKINAC. — In 1883 W. A. Brotherton saw an albino in the county.

MECOSTA. — In January, 1911, Orrin J. Wenzel saw one in the county.

MISSAUKEE. — In 1898 Percy Selous stated that it was common in the county.

MONROE. — Jerome Trombley reports it to have been common at Petersburg in the early days; since 1860 it has been scarce, and in 1910 was growing scarcer year by year.

MONTCALM. — In 1898 Percy Selous reported it rare in the county. In 1911 L. C. Hodges reported it rare at Stanton.

MONTMORENCY. — In 1911 Albert Miller reported it common near Lewiston.

MUSKEGON. — In 1898 R. H. Wolcott reported it common near Whitehall. In July, 1910, T. Moore shot one near Montague.

OGEMAW. — The Museum of Zoölogy has a specimen taken June 20, 1903 at West Branch.

OSCODA. — In 1903 N. A. Wood found it not rare in the county.

PRESQUE ISLE. — In October, 1883, N. A. Wood saw one which had been killed near Black Lake.

ROSCOMMON. — The Museum of Zoölogy has a specimen taken in May, 1904, at Higgins Lake.

SCHOOLCRAFT. — N. A. Wood has seen a specimen which was taken November 15, 1914, near Seney.

ST. CLAIR. — The Museum of Zoölogy has a specimen taken in 1859 at Fort Gratiot.

TUSCOLA. — In the winter of 1863 Samuel Spicer shot several in the county.

Marmota monax monax

Marmota monax rufescens

Woodchuck

Allegan. — In 1914 Isaac Lamoex reported it to occur near New Richmond.

Antrim. — W. E. Hastings reports it common in 1920 in this county.

Crawford. — In 1903 residents reported to N. A. Wood that it was common in the county.

Delta. — In 1895 Edward Van Winkle reported it common at Van's Harbor.

Dickinson. — In 1898 E. E. Brewster reported it rare near Iron Mountain; he had seen only four or five in seventeen years.

Genesee. — In 1910 several old residents reported it to have been always common in the county.

Grand Traverse. — W. E. Hastings reports it common in 1920 in the county.

Hillsdale. — In 1898 T. L. Hankinson reported it common in the county.

Ingham. — In 1898 T. L. Hankinson reported it common near East Lansing.

Jackson. — In September, 1880, N. A. Wood saw several near Napoleon.

Kent. — In 1898 R. H. Wolcott and W. E. Mulliken reported it common at Grand Rapids.

Lapeer. — In 1905 and 1918 several residents reported it common in the county.

Lenawee. — In 1896 N. A. Wood saw several near Milan.

Livingston. — In 1911 N. A. Wood saw several near Lakeland.

Luce. — In 1914 Wm. McGraw reported that he had killed several near Two Hearted Station.

Monroe. — In 1910 Jerome Trombley reported it very common near Petersburg.

MONTCALM. — In 1898 Percy Selous reported it very common near Greenville. In 1911 L. C. Hodges reported it common near Stanton.

MONTMORENCY. — In 1910 Albert Miller reported it common near Lewiston.

OAKLAND. — In June, 1896, N. A. Wood saw several at South Lyon. W. E. Hastings reports it common in 1920 near South Lyon.

OSCODA. — In 1903 residents reported to N. A. Wood that it was common in the county.

OTTAWA. — In 1908 John Driy reported it rare near Holland, one was seen in the fall of 1905.

WAYNE. — In 1897 J. Claire Wood found it common in Woodland Lawn Cemetery.

CITELLUS TRIDECEMLINEATUS TRIDECEMLINEATUS

Striped Ground-Squirrel

CALHOUN. — In 1898 E. L. Moseley reported it plentiful in the county.

CASS. — In 1911 Crystal Thompson found it rare near Cassopolis.

CRAWFORD. — In 1903 residents reported to N. A. Wood that it was fairly common in the county.

DICKINSON. — In 1913 C. V. Woodin reported a few to occur in the sandy barrens of the northern part of the county.

GENESEE. — In 1905 H. B. Baker reported it not common near Flint. In 1910 Samuel Spicer reported it common in Atlas Township.

HILLSDALE. — In 1898 T. L. Hankinson reported many in the county.

INGHAM. — In 1898 T. L. Hankinson took one at East Lansing, the only one he had seen in the county.

JACKSON. — In September, 1896, N. A. Wood found it common near Napoleon.

KENT. — In 1898 resident naturalists reported it common near Grand Rapids, being found only on quite sandy ground.

LIVINGSTON. — In 1910 N. A. Wood found it common near Lakeland.

MONTCALM. — In 1898 Percy Selous reported it common near Greenville. In 1911 L. C. Hodges reported it very common since 1905 near Stanton.

OAKLAND. — In 1920, W. E. Hastings reported it common near South Lyon.

OTTAWA. — In 1908 John Driy reported it rare near Holland.

ROSCOMMON. — July 16, 1903, N. A. Wood saw one near Roscommon.

VAN BUREN. — The Edwardsburg High School has a specimen taken in 1911 at Bangor.

EUTAMIAS MINIMUS NEGLECTUS

Lake Superior Chipmunk

LUCE. — During August, 1914, N. A. Wood found it common in the northeastern part of the county.

MARQUETTE. — In August, 1910, Bryant Walker found it in the Huron Mountains.

TAMIAS STRIATUS LYSTERI

Chipmunk

CASS. — In 1912 it was reported by Crystal Thompson still common near Cassopolis.

CRAWFORD. — In 1903 residents reported to N. A. Wood that it was common in the county.

GENESEE. — In 1910 Samuel Spicer reported it always common in Atlas Township. In 1905 H. B. Baker reported it very common near Flint.

INGHAM. — In 1898 T. L. Hankinson reported it common in the county.

JACKSON. — In September, 1880, N. A. Wood saw several near Napoleon.

KALAMAZOO. — In 1881 N. A. Wood saw it near Kalamazoo.

KENT. — In 1898 R. H. Wolcott and W. E. Mulliken reported it very common at Grand Rapids.

Lenawee. — In July, 1900, N. A. Wood saw several near Milan.

Livingston. — In May, 1912, N. A. Wood saw several near Lakeland.

Marquette. — Bryant Walker of Detroit took a specimen August 15, 1910, in the Huron Mountains.

Monroe. — In 1910 Jerome Trombley reported it quite scarce near Petersburg, where it was quite common about 1880 or 1890.

Montcalm. — The Museum of Zoölogy has a specimen taken in the county in July, 1883, by Morris Gibbs. In 1898 Percy Selous reported it very common near Greenville. In 1911 L. C. Hodges reported it common near Stanton.

Oscoda. — In July, 1903, N. A. Wood saw one near Butler Bridge.

Ottawa. — In 1908 John Driy reported it quite common near Holland.

Saginaw. — In 1902 R. A. Brown reported it common in the county.

Wayne. — J. Claire Wood reports finding in 1897 several nests of newly born young in Woodland Lawn Cemetery.

Sciurus hudsonicus loquax

Red Squirrel

Alcona. — September 20, 1903, N. A. Wood saw several near Bamfield.

Allegan. — In 1914 Isaac Lamoex reported it to occur near New Richmond.

Antrim. — W. E. Hastings reports it abundant in 1920 in this county.

Cass. — In 1912 Crystal Thompson reported it still common near Cassopolis.

Crawford. — In 1903 residents reported to N. A. Wood that it was common in the county.

Delta. — In 1895 Edward Van Winkle reported it abundant at Van's Harbor.

Dickinson. — In 1898 E. E. Brewster reported it common at Iron Mountain.

Genesee. — Samuel Spicer reports that it was formerly very common in Atlas Township, but he took none after 1887. In 1905 H. B. Baker reported it not very common near Flint.

Grand Traverse. — W. E. Hastings reports it common in 1920 in the county.

Ingham. — In 1898 T. L. Hankinson reported it common in the county. The Museum of Zoölogy has a specimen taken in October, 1911, at Lansing.

Iosco. — September 21, 1903, N. A. Wood saw several along the Au Sable River.

Kalamazoo. — The Museum of Zoölogy has a specimen taken by Morris Gibbs in the county.

Kent. — In 1898 R. H. Wolcott and W. E. Mulliken reported it common near Grand Rapids.

Luce. — In 1912 residents of the region reported to N. A. Wood that it was common in the northeastern part of the county.

Mackinac. — In 1890 J. Claire Wood found it common in the county.

Monroe. — In 1910 Jerome Trombley reported it scarce near Petersburg, where it was once common.

Montcalm. — The Museum of Zoölogy has a specimen taken by Morris Gibbs in the county. In 1898 Percy Selous reported it very common near Greenville. In 1911 L. C. Hodges reported it plentiful near Stanton.

Oakland. — W. E. Hastings reports it numerous near South Lyon in 1920.

Ottawa. — In 1908 John Driy reported it not common near Holland.

Roscommon. — In July, 1903, N. A. Wood found it common near Roscommon.

Van Buren. — The Edwardsburg High School has a specimen taken in 1912 at Bangor.

Wayne. — In 1910 J. Claire Wood reported it common near Detroit.

SCIURUS CAROLINENSIS LEUCOTIS

Gray Squirrel

ALGER. — N. A. Wood saw four gray squirrels and a black one killed in October, 1908, near Munising.

ALLEGAN. — In 1914 Isaac Lamoex reported both gray and black squirrels to occur at New Richmond.

BRANCH. — In 1898 E. L. Moseley reported it to occur in the county.

CASS. — In 1911 Crystal Thompson reported gray and black squirrels as formerly common near Cassopolis.

CHIPPEWA. — Joseph H. Steere, in 1910, reported black and gray squirrels scarce near Sault Ste. Marie.

CRAWFORD. — In 1903 residents reported to N. A. Wood that it was rare in the county.

DELTA. — In 1895 Edward Van Winkle reported it not common at Van's Harbor.

DICKINSON. — Albert Terrill in 1909 reported that black and gray squirrels were occasionally taken near Norway.

GENESEE. — Samuel Spicer, an old resident, reports that it used to be common in Altas Township, but in 1910 it was nearly extinct. In 1905 H. B. Baker reported it rare near Flint.

GRAND TRAVERSE. — W. E. Hastings reports it common in 1908 in the county, the gray phase most common.

INGHAM. — In 1898 W. J. Beal reported it common at East Lansing. In 1909 Prof. Chas. Davis, botanist, reported it scarce at Lansing.

IONIA. — The Museum of Zoölogy has a specimen taken September 5, 1878, at Ionia.

KENT. — In 1898 the resident naturalists reported it once common, still numerous, but decreasing in numbers, the black color phase only being found at that time.

LUCE. — Wm. McGraw reports he killed both gray and black squirrels in 1914 at Two Hearted Station.

MACKINAC. — In 1911 Frank Baum reported a few to occur near Gilchrist.

Monroe. — In 1910 Jerome Trombley reported it to be very scarce near Petersburg, where it was once very common.

Montcalm. — The Museum of Zoölogy has a specimen taken in the county by Morris Gibbs September 29, 1883. In 1898 Percy Selous reported it common at Greenville during migrations. In 1911 L. C. Hodges reported it rare at Stanton.

Montmorency. — In 1910 Albert Miller reported the black squirrel common near Lewiston.

Oakland. — W. E. Hastings in 1921 reported a few to occur near South Lyon.

Oscoda. — September 18, 1903, Prof. J. E. Reighard, of the University of Michigan, saw a black squirrel near McKinley; at that time residents reported it scarce in the county.

Ottawa. — In October, 1901, John Driy shot a black squirrel near Holland.

Shiawassee. — Michigan Agricultural College has a specimen labeled Ososso.

St. Clair. — The Museum of Zoölogy has three black squirrels taken in November, 1892, at Port Huron.

Wayne. — In 1910 J. Claire Wood reported it to equal the fox squirrel in abundance near Detroit; from 1888 to 1894 they were abundant in the city markets.

Sciurus niger rufiventer

Fox Squirrel

Allegan. — In 1914 Isaac Lamoex reported it to occur at New Richmond.

Antrim. — In 1920 W. E. Hastings reported a few to occur in the county.

Branch. — In 1898 E. L. Moseley reported it to occur in the county.

Cass. — In 1911 Crystal Thompson found it rather common at Cassopolis.

Charlevoix. — Walter Rodger saw one in June, 1907, and two in the winter of 1910–1911 near Charlevoix.

Chippewa. — Charles Hawkins, a hunter and trapper, reports he killed one in October, 1906, near Whitefish Point P.O. Residents of the region report it very rare.

Genesee. — Samuel Spicer reports it had been numerous in Atlas Township until about 1900. In 1905 H. B. Baker reported it quite common near Flint.

Grand Traverse. — In 1920 W. E. Hastings reported it not so common as formerly in the county.

Hillsdale. — In 1898 T. L. Hankinson reported a good many to occur in the county.

Ingham. — In 1883 H. A. Atkins reported it more common than the gray squirrel in the county; it first appeared in the county about 1863.

Jackson. — In September, 1880, N. A. Wood saw several near Napoleon.

Kent. — In 1898 several resident naturalists reported it common at Grand Rapids, and as preferring open woods with high trees.

Lenawee. — W. J. Beal reports that it was not found in the county until about 1858.

Luce. — Walter Rodgers reports that a hunter in the fall of 1909 saw several and shot one nine miles north of Rexton.

Monroe. — In 1910 Jerome Trombley reported it found sparingly at Petersburg, where it had never been common, though at one time it was much more numerous.

Montcalm. — In 1898 Percy Selous reported it common at Greenville, often being found running over the deep snow on sunshiny days in midwinter. In 1911 L. C. Hodges reported it common at Stanton.

Muskegon. — In 1910 T. Moore reported it not rare near Montague.

Oakland. — In 1920 W. E. Hastings reported a number to occur near South Lyon.

Ottawa. — In 1908 John Driy reported it less common than formerly near Holland.

Presque Isle. — In 1892 Walter Rodger saw one near Black Lake.

SAGINAW. — In 1902 R. A. Brown reported it rare in that county.

WAYNE. — In 1910 J. Claire Wood reported it to still hold its own near Detroit.

GLAUCOMYS VOLANS VOLANS

GLAUCOMYS SABRINUS MACROTIS

Flying Squirrel

CHEBOYGAN. — July 27, 1915, N. A. Wood found a female and five half-grown young in an outside nest of grass and bark, placed about fifteen feet up in a poplar tree at Douglas Lake. The nest was very much like that of the red squirrel and might have been an abandoned nest of that species (*macrotis*).

CRAWFORD. — In 1903 residents reported to N. A. Wood that it was common in the county.

DICKINSON. — In 1898 E. E. Brewster reported flying squirrels common near Iron Mountain. In 1909 A. G. Ruthven saw mounted specimens (*macrotis*) which had been taken near Norway.

GENESEE. — In 1905 H. B. Baker reported flying squirrels quite common near Flint.

INGHAM. — In 1898 T. L. Hankinson reported flying squirrels common at East Lansing.

IONIA. — In 1898 L. J. Cole reported flying squirrels found in the county.

KENT. — In 1898 W. E. Mulliken reported flying squirrels common at Grand Rapids.

LUCE. — In 1914 Wm. McGraw reported that he caught in winter in the northeastern part of the county many flying squirrels in traps set for fur-bearing animals.

MONROE. — In 1910 Jerome Trombley reported flying squirrels common near Petersburg.

MONTCALM. — A specimen taken in the county December 13, 1883, by Morris Gibbs is *macrotis*. In 1898 Percy Selous reported flying squirrels common near Greenville. In

1911 L. C. Hodges reported flying squirrels plentiful at Stanton.

OSCODA. — In 1903 J. Buchanan reported flying squirrels common at Big Creek.

OTTAWA. — In October, 1907, a flying squirrel was seen by John Driy near Holland.

SAGINAW. — In 1897 R. A. Brown reported flying squirrels common in the county.

WASHTENAW. — Walter Koelz has a specimen (*volans*) taken in Ann Arbor August 23, 1922.

WAYNE. — In 1897 J. Claire Wood found flying squirrels numerous in Woodland Lawn Cemetery.

CASTOR CANADENSIS MICHIGANENSIS

Beaver

ALLEGAN. — Isaac Lamoex reports it occurred at New Richmond when he arrived there in 1845.

ANTRIM. — W. E. Hastings reports that old dams can still be found in the county.

CHEBOYGAN. — In October, 1882, N. A. Wood saw houses and dams on Black River, and saw one beaver which had been trapped.

CRAWFORD. — In 1903 residents reported to N. A. Wood that it was rare in the county.

GENESEE. — In 1905 H. B. Baker reported that remains of dams could be seen near Flint.

GRAND TRAVERSE. — W. E. Hastings reports old dams still to be found in the county.

INGHAM. — In 1898 T. L. Hankinson wrote that old residents had seen beaver dams in that county.

JACKSON. — W. C. Weeks reports one caught in 1836 near Napoleon.

KALKASKA. — A. B. Covert reports that beaver were still common in 1882.

LENAWEE. — In 1898 W. J. Beal reported old beaver dams still to be found in the county.

LIVINGSTON. — W. E. Hastings reports one old dam near Green Oak.

LUCE. — Still numerous in the county until at least 1912, as reported to N. A. Wood by residents and hunters.

MONROE. — Jerome Trombley reports that numerous old dams once occurred near Petersburg; some of these dams must have been built as late as 1810, but the beaver were entirely extinct in the region by 1833.

MONTCALM. — In 1911 L. C. Hodges reported that it was formerly common and that dams were still to be seen near Stanton.

MONTMORENCY. — In 1911 Albert Miller reported a few left in the county.

OAKLAND. — W. E. Hastings reports a very few old dams still present near South Lyon.

OSCODA. — In 1903 residents reported to N. A. Wood that a few were left near Royce City and McKinley.

PRESQUE ISLE. — October 15, 1883, N. A. Wood saw one freshly caught near Black Lake.

SAGINAW. — The Museum of Zoölogy has a mounted specimen taken in 1888 near Saginaw.

WEXFORD. — A. B. Covert reported it still common in 1882 near Cadillac.

LEPUS AMERICANUS AMERICANUS

LEPUS AMERICANUS PHAEONOTUS

Snowshoe Hare

ALLEGAN. — It occurred at New Richmond when Isaac Lamoex arrived there in 1845.

ANTRIM. — In 1920 W. E. Hastings reported it common in the county.

CHEBOYGAN. — In 1883 N. A. Wood found it not rare at Black River.

CRAWFORD. — In 1903 residents reported to N. A. Wood that it was common in the county.

GENESEE. — Samuel Spicer reports it was common in Atlas Township until about 1865; he shot many in 1858.

GRAND TRAVERSE. — In 1920 W. E. Hastings reported it common in this county.

INGHAM. — In 1898 T. L. Hankinson wrote that old residents reported it to have occurred formerly in that county.

IONIA. — J. B. Steere reports taking it in the county in the early days.

JACKSON. — In 1898 W. J. Beal reported it still taken by hunters in a large swamp in the county. In the fall of 1907 L. D. Watkins shot one in a big swamp in the county.

LIVINGSTON. — In 1890 Will Drake, formerly of South Lyon, shot sixteen in one day near Pinkney.

LUCE. — In 1914 N. A. Wood found it common in the northeastern part of the county.

MACKINAC. — In 1890 J. Claire Wood found it common in the county.

MONTCALM. — In 1898 Percy Selous reported it rare near Greenville, though common twelve miles north of that place. In 1911 L. C. Hodges reported it formerly common, but then rare, near Stanton.

OAKLAND. — In 1898 A. B. Durfee reported it formerly common in the county.

OSCODA. — In July, 1903, N. A. Wood saw several and secured one near Butler Bridge.

WAYNE. — In 1898 A. B. Durfee reported it formerly common in the county.

SYLVILAGUS FLORIDANUS MEARNSII

Cottontail

ALLEGAN. — In 1898 L. J. Cole reported it common in the county.

ANTRIM. — In 1920 W. E. Hastings reported it common in the county.

BRANCH. — E. L. Moseley reports its occurrence in 1897 at Union City.

Charlevoix. — In 1909 and 1922 Walter Rodger reported it common near Charlevoix.

Cheboygan. — In July and August, 1914, N. A. Wood saw several near Douglas Lake.

Crawford. — In 1903 E. A. Purchase reported it rare in the eastern part of the county.

Eaton. — The Museum of Zoölogy has a specimen taken in the county in December, 1905, by F. S. Hall, of the University of Michigan, who reported it common.

Genesee. — In 1905 H. B. Baker reported it common near Flint. In 1910 Samuel Spicer, an old resident, reported it always common in Atlas Township.

Grand Traverse. — In 1920 W. E. Hastings reported it common in the county.

Hillsdale. — In the late fall of 1878 N. A. Wood shot one near Somerset Center. T. L. Hankinson reports it common near Hillsdale up until 1891; in 1892 it decreased in abundance, and in 1893 and 1894 became very scarce; in 1898 it was still scarce.

Ingham. — In 1898 T. L. Hankinson and L. J. Cole reported it common near Lansing.

Ionia. — In 1898 L. J. Cole reported it common in the county.

Jackson. — In 1910 W. C. Weeks reported it common near Napoleon.

Kent. — In 1898 resident naturalists reported it common near Grand Rapids.

Lapeer. — In 1896 N. A. Wood saw several near Milan.

Livingston. — Since 1895 N. A. Wood has found it common in the southern part of the county.

Monroe. — In 1910 Jerome Trombley reported it present in considerable numbers near Petersburg, but diminishing since 1890.

Montcalm. — In 1898 Percy Selous reported it very common at Greenville. In 1911 L. C. Hodges reported it common near Stanton.

Muskegon. — In 1910 T. Moore reported it abundant near Montague.

OAKLAND. — In 1882 N. A. Wood found it common and shot several near South Lyon. In 1920 W. E. Hastings reported it common near South Lyon.

OTTAWA. — In 1908 John Driy reported it common near Holland.

PRESQUE ISLE. — In 1882 Walter Rodger reported it rare near Black Lake.

VAN BUREN. — The Edwardsburg High School has a specimen taken in 1913 at Bangor.

WAYNE. — In 1910 J. C. Wood reported it common near Detroit.

CERVUS CANADENSIS CANADENSIS

American Elk

ALLEGAN. — Isaac Lamoex reports that it was found at New Richmond when he arrived there in 1845.

GENESEE. — Samuel Spicer reports that antlers have been plowed up in Atlas Township.

GRATIOT. — Wm. J. Foster, of Pompeii, saw a female between 1866 and 1870 in Washington Township, where the male had been killed a short time previously.

HURON. — C. F. Smith, reports that it was common in the county until 1871.

INGHAM. — The Museum of Zoölogy has the basal half of a large set of antlers dug up in Ingham Township in 1907.

JACKSON. — R. W. Bunton, of Ann Harbor, reports a set of antlers dug up at Michigan Center in December, 1920.

KALAMAZOO. — The Museum of Zoölogy has a portion of an antler dug up near Kalamazoo in 1910, and presented by E. T. Seton.

MECOSTA. — A. W. Bennett, attorney, of Big Rapids, writes of a set of antlers found near that place in September, 1915.

MONROE. — Jerome Trombley reports finding a pair of antlers near Petersburg in 1845.

MONTCALM. — Percy Selous in 1898 reported that antlers had been found in that county.

Sanilac. — C. F. Smith reports it was common near that place until the great forest fires of 1871, when it became scarce; previous to that time it occurred in herds of a dozen or more and he had no difficulty in getting all he needed for food.

Tuscola. — Wm. Duncan, of Salem, reports that in 1866 part of a herd from Huron County got over on the Cass River in Tuscola County, and that was the last heard of them. Oscar Douglass, of Hamburg, killed one in Tuscola County in December, 1856. J. Foster, of Pompeii, has seen the head of one which had been killed by an Indian in Tuscola County in 1870 or 1871.

Odocoileus virginianus borealis

White-tailed Deer

Allegan. — It was at New Richmond when Isaac Lamoex arrived there in 1845.

Antrim. — In 1920 W. E. Hastings reported a few yet in the county.

Crawford. — Reuben Ambruster, formerly of Ann Arbor, killed a buck in 1892 near Jack Pine.

Eaton. — A. G. Powell, a resident, shot one in Brookfield Township in 1870, the last one seen in the township.

Genesee. — Samuel Spicer reports it was common in Atlas Township between 1845 and 1850, and was frequently seen until 1860. The father of H. B. Baker states that near Flint the last one was seen in 1880.

Grand Traverse. — In 1920 W. E. Hastings reported a few still in the county.

Ingham. — T. L. Hankinson reports that it has been extinct in the county since about 1858.

Ionia. — L. J. Cole in 1898 reported it had occurred in the county within comparatively recent times.

Jackson. — W. C. Weeks, in 1890, killed near Napoleon the last one known in the county.

Keweenaw. — Deer were introduced on Isle Royale in 1910

by the state game warden; the stock was taken from the semi-domesticated herd on Grand Island, Alger County.

KENT. — W. E. Mulliken and L. J. Cole in 1898 reported it once common near Grand Rapids, and as continuing to within comparatively recent times.

MONROE. — Jerome Trombley reports it was extremely abundant near Petersburg up to 1850, when they began to diminish; three, the last known to him from the county, were killed in 1891. George Grey, a resident, reports three killed in the county in 1900.

MONTMORENCY. — Albert Miller, in 1910, reported it was common near Lewiston.

SCHOOLCRAFT. — E. N. Woodcock in the winter of 1875–1876 saw twenty-five in one day on the banks of the Manistique River.

WAYNE. — A. B. Durfee in 1898 stated it was once common in the county.

RANGIFER CARIBOU CARIBOU

Caribou

CHIPPEWA. — Joseph H. Steere wrote in 1910 that he had seen tracks on the Michigan side along the St. Marys River, and that parties had seen them swim from the Canadian shore to Sugar Island.

KEWEENAW. — C. S. Pierce, state game warden, reported in 1911 that there were at least two large herds on Isle Royale.

LUCE. — Kitson Cobb reports one killed near Soo Junction in November, 1906, by a man who thought it a peculiar deer.

ALCES AMERICANUS

Moose

ALGER. — Wm. J. Foster, of Pompeii, reports that he has seen in Seney the mounted head of a large male killed in 1890 about twenty-five miles north of that place.

CHIPPEWA. — Joseph H. Steere states that it is frequently reported in the vicinity of the Tahquamenaw River, and that he saw tracks of a large one in 1909. He states also that Chase Osborn, former state game warden, in the fall of 1909 several times saw a bull and cow near his cottage on Duck Island in the St. Marys River. N. A. Wood has given the Museum of Zoölogy the antlers of a two-year old male killed near Whitefish Point in 1908.

HURON. — Chas. C. McDonald, a lighthouse keeper, saw a moose in this county about 1870 and heard of others later.

LUCE. — Wm. McGraw saw a male near Two Hearted Station in 1900, and another male at the same place September 21, 1907; signs and tracks were seen also in 1909, 1910, and 1913. J. S. Ligon, of the U.S. Biological Survey, saw a male December 18, 1920, on the Tahquamenaw River fourteen miles north of Soo Junction.

MACKINAC. — Frank Baum in 1911 reported a few to occur near Gilchrist.

MISSAUKEE. — A. B. Covert at one time had the antlers of a male killed in August, 1881, in Union Township.

PRESQUE ISLE. — John Rodger in October, 1883, saw a fine male near Black Lake.

SANILAC. — C. K. Dodge saw the body of one brought to Port Huron, which had been killed in the winter of 1864 in Sanilac County.

SCHOOLCRAFT. — Deer hunters killed a cow in October, 1912, in the northern part of the county; the hunters concerned were arrested and sentenced and the head given to the Museum of Zoölogy. About October 1, 1922, a male was seen about twenty miles northwest of Seney by several persons, among whom was George Banzhof, a graduate of the University of Michigan.

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